Examining the Learning Effects of Segmented Model Demonstrations on the Motor & Cognitive Learning of the Basketball Jump Shot

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SIGNATURE PAGE

DEDICATION

I lovingly dedicate this to my parents, Hector & Norma without whom none of my success would be possible.

ABSTRACT

The purpose of the present experiment was to determine whether learning is optimized when providing the opportunity to observe either segments, or the whole basketball jump shot. Participants performed 50 jump-shots from the free throw line during acquisition, and returned one day later for a 10 shot retention test and a memory recall test of the jump-shot technique. Shot accuracy was assessed on a 5-point scale and technique assessed on a 7-point scale. The number of components recalled correctly by participants assessed mental representation. Retention results showed superior shot technique and recall success for those participants provided control over the frequency and type of modelled information compared to participants not provided control. Furthermore, participants in the self-condition utilized the part-model information more frequently than whole-model information highlighting the effectiveness of providing the learner control over viewing multiple segments of a skill compared to only watching the whole model.

(Keywords: Segmented, Self-control, Technique, Accuracy, Recall-success)

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CHAPTER ONE

1.0 Review of Literature

1.1 Motor Learning and Observation

Learning is inevitable, from the time we are born until death; we constantly acquire new and different capabilities that permit us to functionally respond to all aspects of life (Kantak & Weinstein, 2012). These capabilities can be further specified as motor skills, which are ‘activities or tasks that require voluntary head, body, and/or limb movements to achieve a specific purpose or goal’ (Magill, 2011, p.3). Motor skills are considered fundamental aspects of human life, thus the measurement of these motor skills is vital information in understanding the factors encompassing human performance (Voelcker-Rehage, 2008).

Motor development and motor learning are all well supported disciplines constituting the study of human behaviour. They differ based on the functional interaction between the skill and the individual, as well as the variable used to measure the interaction. Motor development can be defined as the change in movement behaviour, which is the result of the sequential age-related processes. For instance, factors like maturation/aging foster developmental changes, such as a child progressing from a crawl to a walk. Motor learning however, is defined as the relatively permanent change in the capabilities of a motor skill as a function of practice, such as acquiring a Frisbee toss via overt training (Schmidt & Lee, 2011). Thus, not all changes in human movement are developmental, this is why being able to measure the change in movement via practice, enables us to evaluate both the individual’s performance and learning strategies.

Although motor performance and learning are inter-related, there is a clear distinction between both measures of skill attainment. According to Schmidt & Bjork (1992), motor performance is an observed motor behaviour during practice (temporary), whereas motor learning is the resilience of this behaviour that develops over practice and is sustained over time (relatively permanently). Motor performance can be assessed by calculating changes in observable measurements such as reaction time, movement time, and accuracy during practice, while motor learning involves internal neural and cognitive processes that cannot be directly measured (Kantak & Winstein, 2012). An example of motor performance could be an archer striking the arrow 50 cm from the bull's eye. Since multiple external factors, such as augmented information (e.g., result feedback) could have influenced the outcome during practice, motor learning cannot be directly measured. Thus, to infer the relative permanent effects of practice (learning), retention/transfer tests need to be utilized (Kantak & Winstein, 2012).

Retention tests reflect the strength of the motor representation over a set time frame, compared to transfer tests which reflect the generalizability of the skill learned in practice (Kantak & Weinstein, 2012). Transfer and retention tests can either be administered immediately after practice (immediate, +10s) or after a significant time lapse (delayed, +24hr.). The immediate tests are implemented as a method of observing initial differences in performance caused by any experimental manipulation, while delayed retention tests measure the permanence of the level of performance acquired in practice, usually after consolidation occurs (+24 hrs. (Kantak & Winstein, 2012; Walker, Brakefield, Morgan, Hobson, & Stickgold, 2002)). If the individual is able to perform the skill with minimal error during the delayed retention test, then it could be assumed that the individual has learned that specific motor skill. However, it could be that the individual has only learned the skill in that specific practice situation (e.g., specificity of learning effect). Thus, the measurement of skill performance in a different testing context is termed a transfer test.

Transfer tests require individuals to perform motor skills in practice scenarios that differ from those used during the acquisition phase of the experiment (i.e., modifying: distance, weight, position, order of procedure etc. (Kantak & Weinstein, 2012)). If the individual performs well in both the retention and transfer tests than it could be assumed that the memory of the skill is more generalizable. Therefore, transfer tests measure the flexibility of the individual’s motor memory (Schmidt & Lee, 2011)

1.2 Motor Memory Process

The formation of a motor memory involves three interdependent processes: encoding, consolidation and retrieval (Kantak & Weinstein, 2012; Robertson & Cohen, 2006). Encoding occurs during acquisition (practice) when the learner comprehends the goal of the directed motor action. During the encoding process, the learner interprets information associated with the motor task, and forms connections between the goals, movements, and movement outcomes (Robertson, 2009). For example when an individual is learning how to box line dance, they extract important movement information such as: the dance step sequence, timing of dance sequence, direction sequence and ultimately the goal of the dance (complete the box). This relevant movement information is then utilized to create the mental representation of the action.

Following the encoding process, the learner must facilitate off-line processing to strengthen the mental representation of the practiced skill. This off-line processing is essential to learning and is termed consolidation. During consolidation, the mental representation of the skill is cognitively rehearsed and refined, in turn strengthening the retrievability of the motor memory. During this process the learner essentially separates the relevant movement information from the non-relevant movement information, which fosters a stronger mental representation of the motor skill (Kantak & Winstein, 2012). This process only happens in the absence of physical practice, and occurs best over sleep, via the repeated cycles of non-REM, and REM sleep (Siengsukon & Boyd, 2009). Thus, retention of the skill must be measured after a 24-hour time period, to ensure that effective consolidation has occurred. During this retention test, the learner uses a retrieval mechanism to recover the motor memory that was previously encoded, consolidated and stored. The retention test permits the learner to assess the effectiveness of their encoding and consolidating processes, as the skill must be produced in the absence of the independent variable (i.e., video demonstration, feedback). Therefore, this retrieval is the only possible measure that can determine the strength of the motor memory, and subsequent learning (Kantak & Winstein, 2012).

There are multiple factors, especially in the encoding process of learning that can be manipulated to strengthen the learner's motor representation of the skill. Observational practice is viewed as a credible training method (e.g., Bachman, 1961; Landers & Landers, 1973; Martens, Burwitz, & Zuckerman, 1976; Sidaway & Hand, 1993), especially in the case of relatively complex motor skills (Wulf & Shea, 2002). According to Wulf & Shea (2002), the difference between classifying a task as complex compared to simple is based on three interrelated factors. A skill is considered complex if it has several degrees of freedom, if it cannot be thoroughly reproduced in a single session, and if it is ecologically valid such as learning to ski using a simulator (Wulf & Shea, 2002). In contrast, a skill is considered simple if it has one degree of freedom, if it can be reproduced thoroughly in a single session, and if it appears to be artificial such as a sequential key press task (i.e., Shea & Morgan, 1979).

Observational practice could decrease training loads, training fatigue, and injury, which are all potential repercussions of physical practice (Holmes & Camels, 2008). In fact, observational learning is considered one of the most prominent methods for teaching motor skills in both the athletic and educational settings (Sweeting & Rink, 1999).

As mentioned earlier, observational learning allows the individual to engage in multiple cognitive processes, such as: understanding of action, understanding of intention, imitation, and empathy, which may not be as prominent when physically practicing (Rizzolatti & Craighero, 2004). Observation allows the learner to make predictions of the model's behaviour goals, and with repetition, allows for cortical structural changes, reorganization, and reinforcement to occur in the motor architecture (Holmes & Calmels, 2008). This vicarious method of training has shown to be beneficial for the development of the learner's error detection and correction abilities (Black & Wright, 2000; Blandin & Proteau, 2000; Hayes, Horn, Hodges, Scott & Williams, 2006; Hodges, Chua, & Franks, 2003), as well as for the development of both the movement outcome (result), and the movement dynamics (form) of a motor execution (Ashford, Bennett & Davids, 2006; Wulf, Raupach, & Pfeiffer 2005).

Observational learning is unique in function, as it does not involve the typical top-down processing strategy that is utilized in imagery and physical practice. Holmes & Calmels (2008), identify observational learning, as the process of neural stimulation of a brain representation/neural network involving bottom-up sensorial, perceptual and affective characteristics that are primarily under the subconscious control of the observer (Holmes & Calmels, 2008). Bottom-up processing provides the individual with information from the surrounding environment to form a perception of the skill (stimulus-driven), such as observing an expert model performing a dance sequence. In contrast, top-down processing is characterized as the decomposition of the perceptual interpretation based on the individual's past experience, motivation, and expectations (goal-driven), such as trying to perform the expert dance sequence by reading a written instruction set (Gerrig & Zimbardo, 2002). Thus, observational learning encourages bottom-up processing because the individual is able to visually extract specific pieces of movement information from the skill (environmental stimuli), and merge them to form a cognitive representation (mental representation). This representation is then rehearsed so the learner may retrieve it when needed. This learning (social/cognitive learning) phenomenon was primarily investigated by Bandura (1969, 1977, 1986); in order to explore the processes needed to acquire novel motor skills without reliance on overt physical practice. Thus, the following section will review this learning framework constructed by Bandura (1969), and will summarize the four constituent sub-processes that govern learning via observation.

1.3 The Social Learning Theory

Bandura's (1969), social learning theory emphasizes that the majority of human learning occurs as a function of social interaction within an environment. Thus, by observing the actions of others, individuals can acquire the knowledge of skills, rules, strategies, attitudes and beliefs that may not be present when this method is not available (Ferrari, 1996). Also, individuals can learn the usefulness and appropriateness of specific behaviours, by observing models and their consequent behaviour while comparing it to their beliefs concerning the expected outcome of actions (Bandura 1977, 1986).

Bandura's Social Learning Theory (1969, 1977) expands across many avenues of specified learning. For the purposes of this review, the motor skill-learning component of Bandura's Social Learning theory will be further discussed. According to this theory, skill learning is developed through the construction of a mental model. This mental model provides the conceptual representation for a response production, as well as a standard for correcting motor production as a function of receiving feedback (Bandura, 1986). This conceptual representation is created by transforming observed sequences of specific behaviours into visual and symbolic codes, which are then rehearsed cognitively, and modified in order to best replicate the specific motor skill (Bandura, 1969).

In Bandura's Social Learning Theory (1969, 1977), the focus is on the benefits of learning from a model. In fact, providing a model of action is one of the most effective ways to convey information about the parameters for producing a new behaviour (Bandura, 1986). Essentially, observational learning is governed by four fundamental sub-processes (attentional, retentional, motor production, motivational), which operate sequentially to produce a learning effect.

The first component, ‘attentional sub-processes’, regulates what the learner is selectively observing. This process is mediated by two primary components, the modeling stimuli and the observer’s characteristics, each defined by multiple factors. The modeling stimuli are outlined by the specific characteristics of the task (e.g., distinctiveness, affective valence, complexity, prevalence, functional value, etc.), whereas the observer’s characteristics are controlled by specific elements of the individual (e.g. sensory capacity, arousal level, perceptual set, past reinforcement, etc. (Bandura, 1977)). Thus, the significance of the attentional sub-processes when acquiring a new skill may be pre-determined due to the salience, and complexity of the task, as well as the individual’s perception’s deriving from past experiences (Bandura, 1977). An example would be an individual trying to acquire a specific dance sequence. The characteristics of the task would include: the temporal coordination of the dance sequence, the quantity of the sequential steps, and the novelty of the movement. Whereas the elements of the individual include: previous experience, motor coordination, attention of focus, and self-motivation. Therefore, observation of a skill enables the learner to extract significant task characteristics that may not be clearly defined through physical practice alone, such as temporal coordination of extremities.

Simply observing an action however will not be sufficient enough to correctly interpret and reproduce the motor task. Therefore, Bandura’s Social Learning Theory (1969, 1977) isolates an important sub-process responsible for the symbolic representation of observed actions as the ‘retention sub-process’. This sub-process is responsible for actively transforming the observed information into multidimensional symbols that represent structure and function of the task. These multi-dimensional symbols are essentially collections of related movement information (i.e., goal, intention) that collaborate to construct a mental representation of the action. Moreover, once these symbols have been coded, the learner must then mentally rehearse them in order to help hold it in memory (Bandura, 1969). Considering the previous dance sequence example, during the retentional sub-process of social learning, the learner may chunk the sequence into segments of four steps. This action enables the learner to organize and rehearse their perceptual interpretation of the movement, which in turn strengthens their cognitive representation of the motor task. As the learner continues to rehearse these symbolic codes, they begin translating the symbols into actions that are actively stored in memory for future retrieval (Carol & Bandura, 1987, 1990; Ferrari, 1996; Pylshyn & Demopoulos, 1986).

Once the movement pattern has been coded symbolically and mentally rehearsed, the learner must transform these cognitive representations into spatially and temporally appropriate actions. This third stage of the social learning theory is termed the motor production (reproduction) sub-process and is regulated by the conception-matching process. During this sub-process the encoded movement pattern is cognitively organized into a response pattern that approximates the desired movement (Bandura, 1977; Ferrari, 1996). This response pattern will then be compared to the symbolic mental representation of the movement, and any discrepancies between the two serve as indications for corrective action (Bandura, 1977). Using the dance sequence example, during the motor production sub-process of social learning, the learner will transform the mental representation into appropriate spatial and temporal actions. This will then provide them with a comparative measure between what they first observed (modeled action) and their self-produced motor response, further enabling them to detect or correct any error in their movement. Additionally, these discrepancies between the modeled action and their self-produced motor response can represent unattained components of the performance, which in turn can be symbolically recoded to refine the individual's movement response.

The fourth component of Bandura's Social Learning Theory (1969, 1977) is the motivational sub-process, which is characterized by three elements: external reinforcement, vicarious reinforcement and self-reinforcement. The motivational sub-process involves the cognitive representation of the performance and the development of higher incentives that will influence the individual's active involvement for correctly reproducing the skill (Bandura, 1977). In fact, learners express what they find self-satisfying and reject what they personally disprove, making them more likely to adopt the modeled behaviour if they value the outcomes, than if it has unrewarding or punishing effects (Ferrari, 1996). In order to provide partial control over the motivational effects of the modeled skill (Carol & Bandura, 1982, 1985, 1987, 1990), support the use of expert (expert) models compared to learning (unskilled) model demonstration, arguing that the observer will have a better example to follow when constructing a mental representation. Therefore, the method of model demonstration can be considered an extremely influential determinant in the individual's effectiveness of acquiring a novel skill.

The development of the Social Learning Theory (Bandura, 1969, 1977), provided researchers with a detailed framework explaining the specific processes involved in interpreting and reproducing an observed motor skill. Moreover, this theory is unique to the motor learning literature as it does not utilize augmented feedback (KP-knowledge of performance, KR- knowledge of results) as a variable to infer skill learning; in comparison to Adams' (1971) closed loop theory, and Schmidt's (1975) schema theory.

According to Schmidt (1975), four primary sources of information are needed for learning to occur, they are: initial conditions, response specifications for the motor program, the sensory consequences of the movement, and the outcome of the movement. Furthermore, these four sources of information collaborate to construct the recall and recognition schemas (Schmidt, 1975). The recall schema develops the motor program of the movement and is comprised of the relationship between the desired outcome and the initial conditions, while the recognition schema is comprised of the expected sensory consequences of the movement, and the actual outcome (Schmidt, 1975). Similar to the closed-loop theory, feedback in the form of knowledge of results is necessary after every trial in order to strengthen the recognition schema. Thus, both theories conclude that motor learning can only occur if the learner is able to physically practice the motor skill, as well as receive feedback (knowledge of results) after every trial to guide (Adams, 1971), or correct (Schmidt, 1975) movement response. This suggests that learning cannot occur in the absence of movement (through observation), which challenges the theoretical framework encompassing observation and the social learning theory (Bandura, 1969).

Although, both closed-loop and schema theories indicate that physical practice is essential for learning a motor skill, recent research in the neurological and psychological disciplines provide evidence that observing a movement activates similar neural-cognitive processes as when physically practicing (Rizzolatti & Craighero, 2004; Rizzolatti, 2005). Moreover, these neural-cognitive processes are activated automatically at the onset of observation, providing evidence that motor learning involves cognitive processing in the absence of physical movement (e.g., Buccino et al., 2001; Grafton, Arbib, Fadiga, Rizzolatti, 1996; Nishitani & Hari, 2000, 2002). The following section will assess the neurological properties specific to motor skill learning in regards to: motion detection, the mirror neuron system, and error detection and correction of movement.

1.4 Neurological Properties of Observation

According to Blakemore & Decety (2001), the detection of biological movement is hardwired to the human brain at an early age. Swedish psychologist Gunner Johansson (1973) first acknowledged the proposal that the detection of biological motion may be more of an intuitive process. He devised a study in which he video-recorded specific light sources placed on the joints of an actor completing a biological motion (walk pattern), within a dark environment. These video recordings (dot configurations) were then shown to naive subjects, who immediately interpreted the dots as a person walking (Johansson, 1973). This infers that there may be an underlying automatic mechanism that is consistently activated when presented with a biological motion display. To support this claim, several researchers utilized the 'dot display' methodology to determine if subjects could abstract specific traits related to the biological movement. Interestingly enough, not only can naive subjects determine the actual movement pattern (e.g., run, walk), but also they were able to abstract the gender of the individual, specific personality traits and emotions, along with noting the difference in complex actions such as dance patterns (Dittrich, Troscianko, Lea & Morgan, 1996; Kolowski & Cutting, 1978). Thus, even when movement information is limited (i.e., DOT displays) observation renders us the capability to identify and recognize human motion as long that it is in the individual's movement repertoire.

Through the development of advanced neural imaging techniques (i.e., functional magnetic resonance imaging (fMRI), trans magnetic stimulation (TMS), single neuron recording (SNR) researchers have documented similar brain areas being activated regardless of whether the individual is observing, or executing a movement (Grossman, et al., 2000; Grossman & Blake, 2001; Hodges, Williams, Hayes, & Breslin, 2007). The discovery of the Mirror Neuron System (Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992) has provided researchers evidence for explaining observation-based behaviours, such as the automatic process in understanding action and intention, as well as imitation (Buccino, Binkofski, & Riggio, 2004; Holmes & Calmels, 2008; Wohlschlager & Bekkering, 2002).

This mirror neuron system was first discovered in macaque monkeys through a single neuron recording of the ventral premotor cortex (*see*, Di Pellegrino et al., 1992). The monkeys were either required to execute goal-directed hand movements (i.e., grasping/reaching different objects), or observe the same action being executed by the experimenter. The neural-imaging results indicated that the visuomotor neurons, specifically those located in the inferior frontal gyrus (region F5), were activated when the monkey executed the hand-movement, and also when the monkey observed the experimenter executing the same movement. In fact, evidence from both electroencephalographic (Calmels et al., 2006; Cochin, Barthelemy, Roux & Martineau, 1999) and brain-imaging research (Grezes, Armony, Rowe, & Passngham, 2003) have provided evidence of similar neurons existing in humans, strengthening the notion that mirror neurons form the basis of an observation-execution matching system (Holmes & Calmels, 2008). However, the mirror neuron system behaves differently depending on the mode of observed motor behaviour. For instance, viewing a grasping action from a non-biological (non-human) demonstration yielded less effective activation of the mirror neuron system, compared to viewing a grasping action from a human demonstration ((biological) Perani et al., 2001). Thus, the mirror neuron system is most effective when the observed motion is biomechanically possible, biologically possible (human) and familiar to the individual's motor repertoire (Holmes & Calmels, 2008).

Rizzolatti (2005) suggests the mirror neuron system is related to four primary functional roles in humans: understanding of action, understanding of intention, imitation, and empathy. Each time an individual views a motor action completed by another individual, neurons in the observer's premotor cortex are involuntarily activated to interpret the process and objective of the action. Thus, the mirror neuron system consistently transforms visual information into knowledge (Rizzolatti, Fogassi, & Gallese, 2001). Moreover, imitation of an action, specifically only an action that belongs to the movement repertoire of the observer also endorses the automatic activation of neural circulation. Imitating an action activates the neural circulation of the superior temporal sulcus and the frontal and parietal mirror areas (Iacoboni, 2005), as well as the activation of areas involved in motor preparation such as: the dorsal premotor cortex, the mesial frontal cortex, and the superior parietal lobule (Buccino et al., 2004; see Appendix A, for diagram of activated brain areas). Thus, it seems that an individual can generally perceive, interpret and eventually imitate an observed action without physical practice or augmented feedback. To exemplify, Meltzoff & Moore (1977, 1983, 1989), investigated the effects of facial imitation using newborn babies in a nursery. The newborns ranged anywhere from 42 minutes to 72 hours of age, ensuring that the facial expressions they viewed were considered novel. Using infrared-sensitive video cameras to record the newborns mouth movements, results indicated that imitation of adults perturbing their tongues and opening their mouths was demonstrated by the new-borns after only four minutes of observation. Furthermore, the newborns were able to imitate both facial expressions after only viewing twelve demonstrations of each facial expression, supporting the phenomenon that the capacity to observe and imitate movement is developed at birth, and it does not require extensive interactive experience (i.e., physical practice), mirror experience (i.e., feedback of self) or reinforcement history (i.e., feedback of results) to be effective (Meltzoff & Moore 1983, 1989; Meltzoff & Decety, 2003). Furthermore, the infants were able to imitate the appropriate facial expressions without ever receiving any form of augmented feedback (i.e., visual, auditory), therefore the authors suggest that observing a model demonstration affords the learner a proper reference of how to produce the specific skill. Moreover, this proper reference is then be utilized as a comparative measure for detecting and correcting error in the learner's movement response (Black & Wright, 2000; Black, Wright, Magnuson, & Brueckner, 2005; Blandin & Proteau, 2000; Meltzoff & Moore, 1994; Meltzoff & Decety, 2003).

Recent research examining how physical and observational practice affects the learner's error detection and correction mechanisms have concluded that observation enables learners to perform and develop effective error detection mechanisms as efficiently as those who physically practice (Black & Wright, 2000; Black et al., 2005; Blandin & Proteau, 2000). Black & Wright (2000) were interested in examining whether the effects of observational practice manipulated the development of the performers error detection mechanism, and movement production. Seventy-two participants were asked to reproduce a sequential timing task (sequence of digits: 2, 4, 8, and 6) on a numeric keyboard using the right index finger, within a particular goal proportion time (for review see, Black & Wright, 2000). There were six practice conditions: physical estimate (PE), observational-estimate (OE), no-practice-estimate (NE), physical no-estimate (PNE), observational no-estimate (ONE), and a control no practice no estimation (NNE). Retention results indicated that in terms of absolute timing error, the participants who observed the task during the acquisition phase clearly outperformed the no-practice conditions, and were equivalent to those participants receiving constant physical practice (Black & Wright, 2000). Furthermore, the participants who observed physical practice during acquisition reported smaller absolute difference estimation scores in retention, compared to the participants who received no practice, and those who executed overt physical practice (Black & Wright, 2000). Thus, the authors concluded that movement recognition could be achieved via access to exteroceptive information through observation, and that observation allows the learners to perform and develop error detection and correction mechanisms as efficiently as an individual executing overt physical practice (Black & Wright, 2000; Black et al., 2005). The aforementioned conclusions were also supported by Blandin & Proteau (2000), as well as Black and colleagues (2005), in terms of observational practice developing equally efficient error detection mechanisms as those afforded from physical practice alone.

Based on the previously reviewed literature encompassing the neurological properties it is evident that observation of motion is a vital component in recognizing, interpreting, imitating and correcting movement (Bandura, 1969; Black & Wright, 2000; Black et al., 2005; Blandin & Proteau, 2000; Carol & Bandura, 1982, 1985, 1987, 1990; Di Pellegrino et al., 1992; Gallese, Fadiga, Fogassi, & Rizoolatti,1996; Holmes & Calmels, 2008; Iacobani, 2005; Meltzoff & Moore, 1994; Meltzoff & Decety, 2003). However, as humans we respond more effectively when the observed skill is executed by another human (biological) compared to a machine (non-biological (Perani et al., 2001)). This is because we understand that a human demonstrating a skill ensures that the movement is ‘biomechanically possible’ whereas, if we observe a non-biological model (i.e., not human), we have more uncertainty that the movement is biomechanically possible, which results in less effective integration of the neuron system (Stevens, Fonlupt, Shiffrar, & Decety, 2000). This suggests that observation of another human performing a motor skill promotes the adoption of effective learning strategies. Thus, it is essential to review the specific attributes that characterize the effect a demonstration has on an individual’s learning process.

1.5 Modeling

Research focusing on integration of a model demonstration in practice scenarios has exhibited significant results related to skill learning in both short-term (acquisition phase), and long-term (retention/transfer) contexts (e.g., Hayes, Hodges, Huys & Williams, 2007; McCullagh & Meyer, 1997; Wrisberg & Pein, 2002; Wulf et al., 2005; Zetou, Fragouli, & Tzetzis, 1999). Specifically, this research has shown modeling benefits for movement technique (quality and coordination of movements (e.g., Horn, Williams, & Scott, 2002; Magill & Schienfelder- Zohdi, 1996)), and movement outcomes (e.g., Al-Abood, Davids, & Bennett, 2001; Weiss, McCullagh, Smith & Berlant, 1998).

Model characteristics such as: age (Bandura & Kupers, 1964), similarity (Gould & Weiss, 1981) or skill level (Landers & Landers, 1973), as well as external factors, such as demonstration scheduling (Ong & Hodges, 2012; Weeks & Anderson, 2000; Wrisberg & Pein, 2002; Wulf et al., 2005), and demonstration presentation method, such as live vs. video (Kampiotis & Theodorakou, 2006; Rohbanfard & Proteau, 2012), virtual (Kernodle, McKethan, & Rabinowitz, 2008), real vs. slow time (Scully & Carneige, 1998), all influence the learning benefits afforded through observation. Therefore, the aforementioned model characteristics will be discussed and compared to illustrate which components are necessary for effective observational learning.

1.5.1 Skilled vs. Unskilled Models

Perhaps the most logical question to ask when presented a model demonstration is, ‘who’ are the learners to observe? Many controversies exist between ‘who’ the model should be in order to promote the most effective learning. Previous research has investigated the effectiveness of peer-coping and peer-mastery models (Clark & Ste-Marie, 2002; Weiss et al., 1998), skilled vs. unskilled vs. learning models (McCullagh & Meyer, 1997; Meaney, Griffen & Hart, 2005; Weir & Leavitt, 1990) and self-as-a-model (Clark & Ste-Marie, 2007; Onate et al., 2005). Within the repertoire of the motor learning research, each of these modeling methods has proven to be effective in skill learning. However, for the purposes of the present study, the relevant research associated with examining the learning advantages of skilled vs. unskilled models, and the influence these models have on the processes associated with motor skill learning will be discussed.

Research indicates that observing a demonstration, regardless of the model's skill level (i.e., novice, expert), results in significant observational learning benefits (Black & Wright, 2000; Blandin & Proteau, 2000; Hayes, Elliott, & Bennett, 2010; Hodges et al., 2003; Lee & White 1990). Expert models facilitate skill learning because they provide the learner with a correct example of how to perform the task (Al-Abood et al., 2001; Bird & Heyes, 2005; Hodges et al., 2003; Rohbanfard & Proteau, 2011). This expert representation is then used by the participant as a standard of reference for comparing and manipulating their performance responses (Bandura, 1986). However, novice model demonstrations have also been recognized for enhancing task learning. Research suggests that observing a learning model (unskilled), permits the learner to differentiate between a successful and unsuccessful trial. Thus, the individual is able to observe the different movement strategies being demonstrated by the model and essentially detect error (Black & Wright, 2000; Blandin & Proteau, 2000; Rohbanfard & Proteau, 2011). Gould & Weiss (1981) were the first researchers to investigate the effects afforded from skilled vs.

unskilled model demonstrations. Using a leg endurance exercise task, they compared individual's viewing a similar (novice) model demonstrating the leg extension, or a dissimilar (expert) model demonstrating the leg extension. The results indicated that participants viewing a similar (unskilled) model improved their leg extension endurance significantly more compared those participants who viewed a dissimilar (skilled model). However, a major limitation of these results is that no retention test was included, therefore learning could not be assessed (Ste-Marie et al., 2012).

Weir & Leavitt (1990), examined the learning effects afforded by observing peer skilled and unskilled models, with and without knowledge of results performing a dart-throwing task. After sixty practice trials and four retention trials without knowledge of results (KR), participants did not differ significantly in absolute constant error (measure of accuracy), or variable error scores (measure of variability). However, these results were affected by the simplicity of the task, which was to throw a dart and hit the center of the dart board (bull's eye). Thus, due to the simplicity of the task the skill level of the model demonstration provided no strategic benefits for acquiring and replicating the dart throw (Rohbanfard & Proteau, 2011; Weir & Leavitt, 1990). Blandin & Proteau (2000), investigated the influence the skill level of the model (i.e., novice, expert) and practice condition (i.e., overt physical or overt observational practice) had on the individual's ability to learn a time-regulated movement pattern, and effectively detect error. Results indicated that performers observing an expert model completing the task were as effective in developing their error detection mechanisms during retention as well as those who observed a novice model during practice. Moreover, these participants who viewed the novice model during practice developed error detection mechanisms as quickly as those who only exhibited physical practice (Blandin & Proteau, 2000). Thus, even observing a model demonstration that is in the learning stages of skill acquisition can still be considered sufficient observational information for detecting and correcting errors in a learner's movement response.

It can be speculated from the aforementioned research studies pertaining to model type, that similar learning advantages are acquired after viewing skilled and unskilled model demonstrations. However, recent research by Rohbanfard & Proteau, (2011), has suggested that differences in an individual's skill acquisition strategies can be attributed to the type of model observed. They investigated the effects of observing novice vs. expert model demonstrations in comparison to observing a mixed model demonstration (novice & expert) on the acquisition of a sequential timing task. Five conditions were tested: physical practice, observation-novice, observation-expert, observation-mixed and a control condition. Retention results indicated in terms of absolute constant error (total movement time), that the participants who observed the expert model (i.e., expert-observation, mixed) significantly outperformed those individuals who were provided a novice or no model (i.e., novice-observation, physical practice, control) practice scenario. The authors suggest that observation of the skill is essential in enabling an individual to determine key spatial and/or temporal features of the task, which eliminates the necessity to create a cognitive representation of the action through trial and error (Carroll & Bandura, 1982; Rohbanfard & Proteau, 2011). Furthermore, observation of an expert model provided the learner with an accurate template for performing the skill, which aids them in the ability to detect their own response-error. In addition, observing a novice model performing a skill still engaged the learner in information-processing processes, however since the model was inconsistently demonstrating the task, the observer could not create a strong standard of reference, which is vital for movement comparison (Rohbanfard & Proteau, 2011).

Thus, from the previously reviewed literature encompassing the models skill level and the respective learning effects they influenced, it is evident that observation alone led to significant task learning. It is also understood that viewing an expert model provides the learner with a correct reference on how to produce the skill, while observing a novice model actively involves the learner in detecting error in the demonstration (Rohbanfard & Proteau, 2011). Thus, both model types (skill, unskilled) provide benefits to the learning strategy of the individual, however, dependent on the complexity of the task and the skill level of the learner, the model demonstration should be manipulated to facilitate greater skill acquisition. Manipulations may include: frequency of demonstration, scheduling of demonstration, speed of demonstration and mode of demonstration, which will be reviewed in the following section.

1.5.2 Live vs. Video

The mode through which observation is provided (live vs. video) has not received much attention in the motor learning literature. Neurological research suggests that different areas of the brain are being activated depending on the mode of observational information. Research by Kernodle and colleagues (2008), as well as Reo and Mercer (2004), indicate that live and video observation promote similar learning effects in adults. However, a noted limitation to these two research studies is that a combined schedule of physical and observational practice was used, which influences the noted learning differences between live and video observation. Rohbanfard and Proteau (2012), investigated the learning differences between only observing a live model (1^{st} vs. 3^{rd} Point of View), or video model (1^{st} vs. 3^{rd} Point of View) compared to physically practicing a multi-segment timing task. Retention results indicated the observational groups, regardless of their perspective (1^{st} vs. 3^{rd}), or mode (video vs. live), significantly outperformed the control condition in intermediate movement times and total movement time. Furthermore, results indicated there were no statistically significant learning differences evident between those who observed the video demonstration and those who observed the live demonstration. However, video observation includes the advantage of convenience and demonstration consistency, as well as being a more cost- and time-efficient mode compared to live observation (Charlop, Le & Freeman, 2000; Rohbanfard & Proteau, 2012).

1.5.3 Slow- Motion vs. Real Time

The speed of the video demonstration is another feature that has the potential to influence motor learning. Research suggests that based on the instructional information the model is trying to display, both slow motion speed and real time speed could enhance learning. Scully & Carnegie (1998) investigated the effects of slow motion speed, real time speed, and static picture modeling on novices' performing a ballet jumping skill. Results indicated that the slow motion model condition significantly outperformed the other conditions in terms of foot placement upon landing, relative timing, and movement form. However, the slow-motion condition did not perform as well as the other conditions in terms of absolute timing and force production. The researchers suggest that slow-motion demonstration may assist the learner in interpreting the skills of performance related to coordination and relative timing, but may hinder the perception of the control variables required to produce variations of skill performance (e.g., speed of movement, force production (Scully & Carnegie, 1998; Ste-Marie et al., 2012)). Thus, it may be possible that tasks involving high spatial and temporal dependency (i.e., dance sequence), may be interpreted more efficiently and effectively via slow-motion model demonstrations.

It is also essential to understand when to schedule the model demonstration during practice. The following sections will outline when the model should be presented (scheduling), and how often the model should be demonstrated (frequency).

1.5.4 Scheduling of Model Presentation

Observation can be provided before practice, during practice, or it can be offered after practice is complete (Ste. Marie et al., 2012). Although there has been substantial motor learning research completed using model demonstrations as augmented information, only a few have directly investigated ‘when’ observation should be provided. Anderson, Gebhart, Pease and Rupnow (1983), utilized demonstrations to facilitate learning in 7 and 9 year old children practicing a ball-striking task. Although they did not include a retention test, acquisition results indicated a significant difference between those who received model demonstrations and those who did not (Anderson et al., 1983). The absence of a learning test (i.e., retention test) encouraged researchers to further investigate the ‘learning’ effects afforded via scheduling of demonstrations. Weeks & Anderson (2000) explored various methods of integrating observation with physical practice in measuring performance form and outcome scores of volleyball serve. Thirty university students were randomly assigned to one of three conditions in which the timing of the model demonstration varied throughout acquisition. The first condition (all pre-practice), viewed all 10 demonstrations prior to attempting the 30 acquisition trials. The second condition (interspersed), viewed one demonstration before acquisition and then viewed one demonstration every three trials until the practice period ended. While, the third condition (combination) viewed five model demonstrations before commencing acquisition, and then one demonstration every three trials. This combination was continued until the 15th trial, where they had to complete the rest of the practice trials without observing any model demonstrations. Delayed retention scores indicated no differences between the experimental conditions and their accuracy results. However, in regards to form scores, the combination condition significantly outperformed those of the interspersed condition. Thus, the combination condition had the most advantageous interaction of observation and overt physical practice. The researchers suggested that the combination schedule encouraged the participants to reinforce their action representation early in practice via frequent demonstrations, and refine their action response via trial and error exploration in the latter stages of practice (Weeks & Anderson, 2000). These findings support the hypothesis that multiple pre-practice demonstrations are superior to a single pre-practice demonstration in elevating performance scores (McGuire, 1961; Weeks & Anderson, 2000; Weeks & Choi, 1992). Exposure to multiple pre-practice demonstrations followed by a combination of overt physical practice and occasional model demonstrations provide the learner with an initially strong mental representation that can be furthered strengthened by detecting and correcting errors (Weeks & Anderson, 2000).

Contrary to common logic, providing the same model demonstration throughout practice actually undermines learning (Weeks & Anderson, 2000). This is because the learner becomes dependent on the availability of the augmented information and uses this information as a guide for what to do on the next attempt. Thus, this practice scenario comes at the expense of developing internal mechanisms responsible for correcting movement performance (Weeks & Anderson, 2000). Additionally, this practice scenario prohibits the learner from experiencing trial and error learning, which limits the strength of their internal standard of reference, resulting in a weaker error detection mechanism. Therefore, when the learner is required to perform the motor skill without augmented information such as model instruction (i.e., retention test), performance deteriorates (Weeks & Kordus, 1998; Weeks & Anderson, 2000)

From these aforementioned research studies we can conclude that the scheduling of model demonstrations is of significance, especially when being combined with physical practice. It is essential to have multiple pre-practice demonstrations, as it encourages the individual to selectively attend to the relevant task information that needs to be retained early (Bandura, 1986; Weeks & Anderson, 2000). Also, it is encouraged to provide the demonstration periodically throughout practice so long that it is coupled with physical practice trials to promote trial and error learning (Weeks & Anderson, 2000). Therefore, not only is the scheduling of model demonstration significant in promoting effective learning, but so is the frequency. Thus, the following section will compare and contrast the relevant research related to the frequency of model demonstrations and the effect on motor learning.

1.5.5 Frequency of Model Demonstration

One of the first researchers interested in examining how many times a model demonstration should be provided during practice were Sidaway & Hand (1993). They examined if the frequency of model demonstrations would affect the performance accuracy of individuals executing a golf swing. Participants were randomly assigned to one of four conditions: The 100% group (viewed a correct model before each physical trial), the 20% group (viewed a correct model once every five physical trials), the 10% group (viewed a correct model once every 10 physical practice trials), and a control condition who received only the initial instruction. After 150 practice attempts and 30 retention trials, results indicated that all groups had significantly improved their golf swing accuracy. Furthermore, the 100% group performed significantly better in the retention test compared to the other three conditions, suggesting that displaying a model demonstration before each practice trial does not result in the learner becoming dependent on the frequent availability of augmented information contradicting the guidance effect hypothesis (Sidaway & Hand, 1993). The authors indicate that frequent model demonstration is an effective and powerful strategy in facilitating motor learning (Sidaway & Hand, 1993). However, in this research study the accuracy of the golf swing was being considered the skill learning determinant. Thus, participants could have facilitated a completely unorthodox and inefficient golf swing, and yet be considered to have learned the task based on an accurate end result.

Therefore, Wrisberg & Pein (2002), decided to extend Sidaway and Hand's (1993), research by first, allowing certain individuals control of how often they could view a correct model demonstration during acquisition, and secondly, testing a skill in which executing proper form (i.e., technique) is also considered a measure of learning. Thus, forty-five novice college students were asked to reproduce the badminton long serve. The task required the participants to attempt a shot and have it land as deep as possible in the singles service zone, as they were analyzed on form (5 technique components, 1 point per component) and accuracy. The participants were divided into three conditions, an all-model condition (viewed demonstration prior to each attempt), a self-control condition (viewed demonstration on request), and a no-model condition (control, viewed no demonstrations). Participants were asked to complete three separate practice sessions (3 days) consisting of 31 trials per session. All participants were then asked to return for a fourth testing session (retention, fourth day), in which all participants across all conditions completed 11trials without viewing the model. The delayed retention results showed that the all-model and self-control conditions significantly outperformed the no-model condition in regards to serving form, even though accuracy scores did not differ significantly between groups, nor did the form scores between the all-model and self-control conditions (Wrisberg & Pein, 2002). Thus, it could be postulated that the badminton long serve skill used in the experiment was a skill in which the result of the task (accuracy of serve) was not dependent on performance of the task (proper technique). Although the two conditions that viewed demonstrations did not differ in their performance scores, an interesting pattern was noticed, the self-control participants only selected to use the demonstration on 9.8% of their practice trials, even though they were provided the opportunity to view it on every trial. Furthermore, of the requested demonstrations, 82% occurred within the first half of trials on the first day of practice (Wrisberg & Pein, 2002). This lends support to the observational learning literature in regards to utilizing demonstrations early in practice as an effective and efficient method of obtaining a general idea of the desired movement pattern, or as a means of comparing and adjusting individual inaccurate performance (Wrisberg & Pein, 2002). However, since the authors in this research project did not include a 'yoked' condition (participants who cannot self-determine their augmented information and follow a self-control counterparts schedule), it is difficult to determine if the learning advantages of the self-controlled condition are attributed to the fact that the participants could self-select the model frequency (and schedule), or the effect of the reduced modeling frequency.

Therefore, to extend the previous research study and address the aforementioned limitation (i.e., absence of yoked condition) Wulf and colleagues, examined the learning effects afforded when comparing a self-controlled modeling condition with a 'yoked' condition. This would permit the researchers to determine if skill acquisition is a function of providing participants control over their augmented information or, if skill learning is simply a result of all the participants receiving augmented information, regardless of self-control. Thus, in this experiment, twenty-six novice university students were randomly assigned (with the exception of gender—matching the groups) to one of two conditions, self-control (n=13) or yoked ($n=13$). Participants were asked to reproduce the basketball jump shot from the center of the foul line and were asked to concentrate on their performance technique. A video of a skilled model performing the basketball jump shot could either be requested (self-control) or was provided at the intervals of practice in which their self-control counterparts viewed the video (yoked). Participant's motor performance was video recorded then assessed by expert raters who scored each motor performance based on meeting specific technical components of the jump shot (maximum score possible was 12). Movement accuracy was also measured on a five-point scale based on the success of the shot. Participants practiced 25 practice trials with the only difference being that the self-control performers had control over the frequency of the model presentations and the yoked performers did not. All participants were then asked to return a week later to perform a retention test consisting of another 10 trials; however, none of the participants were able to view the model demonstration.

Results showed the self-control condition had relatively higher form scores during practice, and retention than their yoked counterparts. Thus, skill acquisition was more efficient and effective based on providing the participants control over their augmented information (model demonstration). Interestingly, the two groups did not differ in movement accuracy scores during both phases of testing, even though one of the conditions had the predictability of model presentations (Wulf et al., 2005). The self-control participants in this research study requested the model presentations on an average of 1.5 trials (5.8%), compared to the self-control participants in the Wrisberg and Pein (2002), study who requested the model demonstrations 9.8% of the time. These results combined, indicate that the common frequency of model demonstrations lie between 5.8- 9.8% of the practice trials (Ong & Hodges, 2012; Wulf et al., 2005). Also, the authors indicate that even though the participants had control over the frequency of model demonstrations, the demonstration itself may have contained too much information for the learner to extract effectively (Scully & Newell, 1985; Wulf et al., 2005). Thus, if the learner is provided the ability to control the proportion of task information they can observe, they may be able to guide attention to specific aspects of the movement pattern they were relatively uncertain about (Wulf et al., 2005). This method of presenting the model would be expected to foster a more efficient and effective information-processing capability as a consequence of being able to isolate the essential technique components of the motor task, and the relationships between those components (Wulf & Shea, 2002).

1.6 Challenge-Point Framework

Thorough research has concluded that practice is the most important factor responsible for the permanent improvement in the acquisition of motor skills (Adams, 1971; Fitts, 1964; Guadagnoli & Lee, 2004; Magill, 2001). Specifically, if all other factors are held constant then skill improvement is positively related to the amount of practice completed (Guadagnoli & Lee, 2004). According to the Challenge Point Framework (Guadagnoli & Lee, 2004), learning is related to the amount of information available and interpretable in a performance scenario, which is defined by the functional difficulty of the task. Essentially, information is seen as challenging to the learner, however when information is present there is potential to learn from it. The authors outline three specific corollaries: a) learning cannot occur in the absence of information, b) learning will be retarded in the presence of too much or too little information, and c) there is an optimal amount of information, which differs via skill level of the learner, and difficulty of the to-be-learned task (Guadagnoli & Lee, 2004). Task difficulty consists of two broad categories: Nominal task difficulty and Functional task difficulty. Nominal difficulty is the constant amount of task difficulty regardless of who is performing it, and where it is being performed (i.e., shooting a basketball jump shot), whereas, functional difficulty is defined by how challenging the task is relative to the participants skill level (i.e., novice vs. expert), and the conditions that it is being performed under (i.e., self-control vs. yoked vs. control). Thus, performance of a task with low nominal difficulty would be expected to be superior in all groups of performers regardless of their individual skill level. However, as the nominal difficulty increases, the performance level of the learners will decrease according to their initial skill level. Thus, a novice's performance will decrease most rapidly, while an expert's performance is only expected to decrease at the highest level of nominal difficulty (Guadagnoli & Lee, 2004). In contrast, a practice scenario with low functional difficulty would result in decreased performance scores for all learners, as the task information available is minimal. This suggests that as the functional difficulty of the task increases (i.e., greater quantity of task information), so does the information available, which in turn benefits a novice's motor performance more significantly than expert's motor performance (Guadagnoli & Lee, 2004).

Essentially, the framework relates the individual's skill level with the task difficulty. However, there is a performance-learning paradox as increases in task difficulty diminish performance and enhance learning potential (Guadagnoli & Lee, 2004). Thus, an optimal challenge point exists where learning is maximized and compromises to performance are minimized. Logically, substantially increasing the functional difficulty of the task would result in the most availability of interpretable information; however, individuals have a limit as to how much information they can interpret and if that is exceeded than performance is expected to decrease. Therefore, this optimal challenge point has to incorporate the individual information-processing capacity of the learner, in addition to the nominal and functional task difficulty to be most effective. Although the framework is not based on self-control research, it does offer a viable mode to understanding self-controlled contexts (e.g., racquet size; Andrieux, Danna, and Thon, 2012).

1.7 Self- Controlled Learning

Extensive research suggests that practice is considered the single most important factor accountable for the permanent improvement in the ability to perform a motor skill (Fitts, 1964; Guadanogli & Lee, 2004; Magill, 2001; Marteniuk, 1976; Newell, McDonald & Kugler, 1991) More recently, it has been documented that motor skill learning is enhanced substantially if the learner is given some control over their practice conditions (Chiviacowsky & Wulf, 2002, 2005; Chiviacowsky, Wulf, Medeiros, Kaefer, & Tani, 2008a; Chiviacowsky, Medeiros, Kaefer, Wally, & Wulf, 2008b; Patterson & Carter, 2010; Patterson & Lee, 2010; Sanli, Patterson, Bray & Lee, 2012). Allowing the performer control over specific practice conditions has demonstrated benefits in the efficiency of motor skill learning. Especially in the frequency of augmented feedback (Chen et al., 2002; Chiviacowsky & Wulf, 2002, 2005; Chiviacowsky et al., 2008a; Chiviacowsky et al., 2008b; Janelle, Kim, & Singer, 1995; Janelle, Barba, Frehlich, Tennant, Cauraugh, 1997; Patterson & Carter, 2010), in the use of assistant devices (Wulf & Toole, 1999), the frequency of model demonstration (Wrisberg & Pein, 2002; Wulf et al., 2005), and the organization of practice repetitions (Keetch & Lee, 2007; Sanli & Patterson, 2009; Wu & Magill, 2004). Furthermore, research has indicated that motivation levels to learn the task are increased (Chiviacowsky & Wulf, 2002;

Chiviacowsky et al., 2008a; Janelle et al., 1995, 1997; Wulf, Chiviacowsky, & Lewthwaite, 2010), along with an enhancement in both the learners' information processing (Janelle et al., 1995, 1997; Wulf et al., 2005), and subjective error estimation capabilities (Patterson & Carter, 2010).

Self-control often referred to as self-regulation or self-choice, is essentially the learners' ability to control a task variable throughout the duration of practice (Magill, 2011). As suggested by Zimmerman (1990, 1994), self-controlled learning promotes the utilization of metacognitive, motivational and behavioural processes. In terms of the metacognitive influence, self-controlled learning offers the individual the ability to plan, organize, self-monitor and self-evaluate their performance at various points. This has been shown to increase self-efficacy scores via increased intrinsic motivation (Deci & Ryan, 2000; Zimmerman, 1994). Self-controlled learning also influences the behavioural processes via the individual's ability to create an optimal environment in which they can maximize their learning. This can include inquiring information, seeking advice, locating places and partners that will most likely increase learning (Zimmerman 1990, 1994).

Research has indicated that self-control participants develop more in depth information processing abilities during practice (McCombs, 1989; Wulf, Shea, Lewthaite, 2010). In fact, self-controlled learning has shown significant correlations with elaborative and integrative strategies, which result in a deeper understanding of the to-be-learnt material, in comparison to simple rehearsal strategies (Entwistle, Entwistle, & Tait, 1993). This can be contributed to self-controlled learning encouraging performers to try out different movement strategies compared to those without control (Ferrari, 1996; Wulf

& Toole, 1999). Janelle and colleagues (1995) examined the learning effects of self-controlled movement-related feedback (knowledge of performance, KP) on novice learners performing an underhand ball-tossing task. Sixty participants were divided into five distinct conditions, these were: no feedback (control) condition, a 50 % KP condition, a summary KP condition, a self-controlled KP condition and a yoked condition. Results indicated that when learners were given control over the frequency of the KP feedback, they significantly out-performed their yoked counterparts during retention. Furthermore, the self-control performers only requested the feedback (KP) on an average of 7% of the trials, indicating that perhaps the learner is more actively involved when given control over specific practice features (Janelle et al., 1995). Janelle & colleagues (1997) extended this research by examining the learning effects afforded from receiving KR feedback (destination of toss) compared to receiving summary KP or self-controlled KP feedback. The task used was the same underhand ball toss utilized in their previous research study (e.g., Janelle et al., 1995). Upon completing 200 acquisition trials and 20 no-feedback retention trials, results supported their previous findings that learners with control over the frequency of feedback enhance learning in retention compared to those conditions without control of feedback frequency. Furthermore, providing feedback as the movement result (KR) did not improve the technique and accuracy scores of the learners compared to providing feedback about movement form (KP) (Janelle et al., 1997). Therefore, these findings suggest that providing the learner control over feedback during practice enhances the information processing efficiency of the individual, as they are more actively involved in the individualization of their practice context.

1.8 Gap in Literature

There has been extensive research supporting the learning benefits associated with a self-controlled practice context. The majority of the research has limited its results to controlling such practice variables as augmented feedback (e.g., Chen, Hendrick, Lidor, 2002; Chiviacowsky & Wulf 2002, 2005; Chiviacowsky et al., 2008a; Chiviacowsky et al., 2008b; Janelle et al., 1995, 1997), and frequency of whole model demonstrations (Wrisberg & Pein, 2002; Wulf et al., 2005). However, providing the learner control over a model demonstrating multiple technique segments of the motor skill remains an identifiable gap in the literature.

Given our understanding from previous neurological research, observation of biological motion automatically activates a complex network in the brain consisting of the occipital, temporal and parietal visual areas (Rizzolatti & Craighero, 2004). Furthermore, this complex cognitive network (mirror neuron system), is most effective if the observed skill is being demonstrated by another human, compared to a non-biological model, such as a robotic arm (Perani et al., 2001). Thus, it is assumed that humans are hard-wired for understanding action, understanding intention and imitating observed human movement (Meltzoff, 1993; Rizzolatti & Craighero, 2004; Rizzolatti, 2005). Moreover, these automatic cognitive processes aid in developing the basis of an observation-execution matching system, facilitating error detection and correction (Holmes & Calmels, 2008).

Substantial research supports the hypothesis that observational practice is a valuable method for acquiring skills of high complexity (i.e., basketball jump shot

(Bachman, 1961; Landers & Landers, 1973; Martens et al., 1976; Sidaway & Hand, 1993)), especially when combined with physical practice (Shea, Wright, Wulf, Whitacre, 2000; Wulf, Clauss, Shea, and Whitacre, 2001). This is because there is fundamentally more for the learner to 'see', thus more for the learner to 'extract' when observing complex skill demonstrations (Wulf et al., 2005). Moreover, observation enables the learner to interpret important information regarding appropriate coordination patterns, as well as subtle requirements of the task such as proper limb positioning (Johansson, 1973), which cannot be done as effectively via physical practice, due to the high demands on cognitive resource (Wulf & Shea, 2002). However, if the task is of high complexity (whole-body action), the demonstration itself may contain too much movement information for the novice learner to interpret effectively, which often results in the learner concentrating on the end-result of the movement (Breslin, Hodges & Williams, 2009). This, in turn limits the learner's capability of properly acquiring the specific movement strategy needed to effectively produce the to-be-learned skill, resulting in poor performance & retention (Savelsbergh & van der Kamp, 2000).

Thus, the gap in the research is to determine how we can encourage proper retention of a whole-body action, in addition to task success, via observational learning and physical practice (Breslin et al., 2009). Specifically, in the case of complex movements that require the control over several degrees of freedom, such as dynamic sport skills (Hodges et al., 2007; Wulf & Shea, 2002). Perhaps, it may be that the stimulus the learner is observing (i.e., model demonstration) contains an overwhelming amount of movement information, which hinders the information processing capabilities of the learner. Therefore, if complex skills can apportioned into segments that isolate fundamental technique components, such as a basketball jump shot into its coordination and release components, it may be possible that observing these skill segments will result in more effective and efficient information-processing capabilities, as well as subsequent skill acquisition. Thus, the present research experiment will address this gap in motor learning.

CHAPTER TWO

2.0 Introduction, Purpose (s), Research Questions, Hypotheses, & Assumptions

2.1 Introduction

Extensive research indicates that observation is an important tool for motor skill learning (Blandin & Proteau, 2000; Carroll & Bandura, 1982; Hayes et al., 2007; Landers, 1975; Martens et al., 1976; McCullagh & Meyer, 1997; Pollock & Lee, 1992; Wrisberg & Pein, 2002; Wulf et al., 2005; Zetou et al., 1999). Observational practice facilitates exclusive information processing procedures that may not be present when physically practicing. Primarily, the cognitive resources utilized when physically practicing a skill limit the learner's capability to develop a proper standard of reference for correctly producing the skill, as well as the capability to develop mechanisms for the detection and correction of errors (Blandin & Proteau, 2000; Carroll & Bandura, 1990). Specifically, information related to appropriate coordination patterns and subtle requirements, which would be difficult, if not impossible to do when performing a new task, due to the high demand on cognitive resources (Wulf & Shea, 2002). Thus, when we practice via observation there may just be more information to 'see', and thus 'extract' providing the learner with a detailed 'representation' on how multiple subcomponents collaborate to represent the whole task (Wulf & Shea, 2002). Observational practice limits the demand on the learner's motor system, which in turn decreases physical training load, training time, fatigue, and potential injury (Holmes & Calmels, 2008). Therefore, it is crucial to understand what properties characterize effective and efficient motor learning via observation.

Model demonstrations are characterized by multiple influential factors such as: age (Bandura & Kupers, 1964), similarity (Gould & Weiss, 1981; McCullagh, 1987), status (McCullagh, 1986), or skill level (Landers & Landers, 1973). Research suggests that expert model demonstrations are most preferred in a motor learning practice scenario, as it provides the learner with an accurate template of how to properly produce the skill. Furthermore, this accurate template is then used as a reference for detecting and correcting error in their own performance, eliciting a stronger mental representation of the skill (Proteau & Rohbanfard, 2011). In contrast, when a learner observes a novice model demonstrating a skill, they are provided with trial-to-trial variability in the models performance. This is effective for recognizing and correcting error, however since the novice model is not demonstrating the correct standard of reference, the observer is receiving less accurate information, limiting their efficiency in skill acquisition (Proteau & Rohbanfard, 2011). Thus, as long as the participant is provided an expert model demonstrating a skill, the individual learning benefits are enhanced via observation of a correct standard of reference.

Bandura's social learning theory (1969, 1977, 1986), argues that observational learning is governed by four essential pre-requisites: attention, retention, reproduction, and motivation (Fagundes, Chen, & Laguna, 2013). The attentional sub-process is responsible for selectively attending to, and coding relevant task information offered through the model demonstration. The retentional sub-process is responsible for utilizing the interpreted task information to formulate a cognitive representation of the movement. The reproductional sub-process is responsible for transferring the cognitive representation of a movement to overt motor movement production. Lastly, the motivational sub-process is characterized by the willingness of the learner to reproduce the observed movement, via positive incentives (i.e., internal/external rewards, self-satisfaction). Essentially, the attentional and retentional sub-processes are necessary for cognitive acquisition, while the reproductional and motivational sub-processes are necessary for motoric performance (Laguna, 2008).

Attention to the model's detail is necessary in formulating an appropriate blueprint for action that can be stored in memory, and later extracted to guide motor production (Fagndes et al., 2013). In fact, research has demonstrated that self-control enhances learning because it allows the learners to increase motivation (i.e., Janelle et al., 1997), and actively explore more movement strategies (Chen & Singer, 1992; Wulf & Toole, 1999). Specifically controlling practice conditions such as: frequency of augmented feedback (Chen et al., 2002; Chiviacowsky & Wulf, 2002, 2005; Chiviacowsky et al., 2008a; Chiviacowsky et al., 2008b; Janelle et al., 1995, 1997; Patterson & Carter, 2010), the use of assistant devices (Wulf & Toole, 1999), the frequency of model demonstrations (Wrisberg & Pein, 2002; Wulf et al., 2005), and the organization of practice repetitions (Keetch & Lee, 2007; Sanli & Patterson, 2009; Wu & Magill, 2004) have all resulted in enhanced skill learning. Among many other reasons (*see*, Sanli et al., 2012) self-control benefits skill acquisition efficiency because the learner is able to tailor their practice according to their own individual capabilities and needs (Wulf, 2007). Thus, having the opportunity to optimally challenge their cognitive and motor processes via feelings of competence and autonomy (Su & Reeve, 2011).

According to Guadagnoli & Lee's (2004) Challenge-Point Framework, optimal learning is related to the information available and interpretable in a performance scenario. Two types of task difficulties, which exist and interact to define the complexity of a skill, characterize this information. Nominal difficulty is the constant amount of task difficulty regardless of who is performing it and where it is being performed (i.e., shooting a basketball jump shot), whereas, functional difficulty is defined by how challenging the task is relative to the participants skill level (i.e., novice vs. expert) and the conditions that it is being performed under (i.e., self-control vs. yoked vs. control). Thus, although the nominal difficulty of the task stays relatively static, modifying the functional difficulty of the task (i.e., affording self-control over model demonstrations) may decrease task complexity, and allow skill acquisition to be within the information-processing capabilities of the learner. Although the framework is not based on self-control research, it does offer a viable mode to understanding self-controlled contexts (i.e., racquet size; Andrieux et al., 2012).

In 2005, Wulf and colleagues examined learning differences between learners who were afforded control over model demonstration frequency (self-control), and learners who were not given control over model demonstration frequency (yoked, followed self-control counterparts observation schedule), on the technique and accuracy acquisition of the basketball jump shot. This study combined both observational and self-control learning contexts. Results indicated that the self-control learners were significantly superior in technique scores compared to the yoked learners, however not in accuracy scores. Furthermore, the results also indicated that the self-control participants only managed to acquire 34% of the technique components. Therefore, although the action of controlling model demonstration frequency was advantages, there was a limit as to how effective the model demonstrations were in relaying interpretive movement information to the learner. Recent research indicates that if the observed skill is of high complexity (i.e., basketball jump shot) the demonstration itself may contain too much movement information for the learner to interpret effectively, which often results in the learner concentrating on the end-result of the movement (Breslin et al., 2009). This in turn limits the learner's capability of properly acquiring the specific movement strategy needed to effectively produce the to-be-learned skill, which results in a poorer performance & retention (Savelsbergh & van der Kamp, 2000). Additionally, even when the learner is provided control over the observation frequency of the model demonstrations (Wulf et al., 2005), technical acquisition is limited. Thus, an identified gap in the research is to determine how we can encourage proper retention of a whole-body action, in addition to task success, via self-controlled observational learning (Breslin et al., 2009) of a complex sport specific motor skill (Hodges et al., 2007; Wulf & Shea, 2002). If complex skills can be broken down into their fundamental components, such as a basketball jump shot into its coordination component phase, and release component phase, then perhaps having the choice to observe these skill segments may enhance skill acquisition. It could be possible that observing skill segments may lessen the information load that needs to be interpreted in one instance, which would allow the learner more time to properly code and retain the observed information. Furthermore, if the learner has the choice to observe the segmented skill demonstrations in addition to the whole model demonstrations, they may establish a more optimal observation strategy based on components of the skill they have or have not yet acquired. Or, an optimal observation strategy utilized as a reference to detect and correct errors in their own motor production. Therefore, the goal of the present research study was to determine if choice to observe different model demonstrations (whole, segments (coordination, release), no) throughout practice, would result in superior acquisition of the basketball jump shot compared to not possessing model choice (yoked) or not having the opportunity for model observation (control).

2.2 Purpose(s)

The first objective of the proposed experiment was to determine whether the acquisition of proper jump shot **technique** was differentially facilitated by affording learners the opportunity to select and view the whole model, segmented model (i.e., various segments of the jump shot independently), or no model demonstration of the jump shot technique, compared to those who were not afforded choice or observation. The second objective was to determine whether the **accuracy** (i.e., number of successful baskets) of novice performers learning the proper technique of the basketball jump shot was differentially impacted by affording learners the opportunity to select and view the whole model, segmented model (i.e., various segments of the jump shot independently), or no model demonstration of the jump shot, compared to those who were not afforded choice or observation. The third objective was to determine whether novice performer's **recall success** of the specific jump shot technique components differed as a result of the information being controlled by the learner (i.e., whole model, various segments of the jump shot independently, or no model), compared to those who were not afforded choice or observation. The fourth objective was to determine whether novice performer's **motivation** to learn the proper jump shot technique differed as a result of the information being controlled by the learner (i.e., whole model, various segments of the jump shot independently, or no model), compared to those who were not afforded choice or observation. The final objective was to determine if there was a **modification in the learning strategy** (frequency of choosing specific augmented observation information) of the self-control participants when afforded choice of segmented model demonstrations in addition to whole model and no model demonstrations.

2.3 Research Questions:

1. Does affording the learner control over the information of the model demonstration (whole vs. segmented, vs. no) differently affect their capability to acquire proper *basketball jump shot technique*, compared to those without control or observation?
2. Does affording the learner control over the information in the model demonstration (whole vs. segmented, vs. no), differently affect their capability to acquire proper *basketball jump shot accuracy* (i.e., outcome success), compared to those without control or observation?
3. Does affording the learner control over the information in the modelled display (whole vs. segmented, vs. no), differently affect their recall success (cognitive representation of the biomechanic components) of the task compared to those without control or observation?
4. Does affording the learner control over the information in the modelled display (whole vs. segmented, vs. no), differently affect their *motivation* to learn the task compared to those without control or observation?
5. Does affording self-control learner's observation choice of segmented model demonstrations in addition to whole and no model demonstrations alter their *learning strategy* during practice?

2.4 Hypotheses

1. The SELF-CONTROL condition would achieve higher form scores (i.e. technique) during the acquisition period and retention test compared to the YOKED and CONTROL conditions (Wrisberg & Pein, 2002; Wulf et al., 2005).

2. The SELF-CONTROL condition would achieve higher accuracy scores (i.e. outcome success) during the acquisition period and retention test compared to the YOKED and CONTROL conditions (Wrisberg & Pein, 2002; Wulf et al., 2005).

3. The SELF-CONTROL condition will achieve higher recall success scores compared to the YOKED and CONTROL conditions (Patterson & Lee, 2010).

4. The SELF-CONTROL condition will achieve higher motivation scores compared to the YOKED and CONTROL conditions (Chiviacowsky et al. 2008a).

5. The SELF-CONTROL participants will frequent the segmented model demonstrations more often than the whole model and no model demonstration during the acquisition period (*yet to be investigated in motor learning literature,* Guadagnoli & Lee, 2004).

2.5 Assumptions

1. All participants were honest about their previous basketball knowledge and/or experience
2. All participants provided appropriate cognitive and physical effort when completing all testing phases and did not practice the skill/task in between testing periods
3. All participants received the same incentive; therefore, all participants were motivated to complete the task.

CHAPTER THREE

3.0 Methods

3.1 Participants

Participants included thirty-six undergraduate students (N=36), both males (n=12), and females (n=24), who were enrolled at Brock University. Participants were considered to be novel to basketball if they haven't played/participated in an organized basketball game or team (i.e., club, school) since the 7th grade (Cleary, Zimmerman, and Keating, 2006). Participants were asked to proclaim their dominant hand before participating, and only right-handed individuals were tested (Okazaki & Rodacki, 2012; Wulf et al., 2005). The experimenter also recorded both the height and right arm length of each participant, to account for initial individual differences.

Upon meeting the requirements to partake in the research experiment the participants were randomly assigned to one of three conditions, balanced for gender (4 males and 8 females for each condition, respectively): SELF- CONTROL, YOKED and CONTROL (n=12), with the restriction that each SELF-CONTROL participant was paired with a YOKED participant of the same gender. All participants completed university-approved ethical consent forms before participation, and received course-credit after completing the experimental protocol. All participants were informed they will (a) have to practice the jump shot on two separate occasions, (b) complete a total of 50 physical practice trials (10 blocks of 5 trials), and (c) be retested 24 hours later. All participants were naïve to the purposes of this study.

3.2 Task & Apparatus

During the acquisition and retention periods, participants performed the basketball jump shot on a hardwood floor basketball court (28m x15m) in Brock University's Varsity Gymnasium. The participants performed the jump shot on a standardized basketball net with a height of 3.05m and a rim diameter of .46 m. They were required to shoot from a distance of 4.57 m from the backboard (free throw line). Participants shot 5 NBA regulated (C=75.88 cm, 567-624 g) multi-coloured basketballs (360 Athletics, USA), which were placed on a basketball rack (2m) behind the participant. Considering that the jump shot attempt needed to be completed within a 15 second bandwidth, a digital scoreboard (Molten Inc., Reno, NV), was placed (1m) below the center of the basketball net and was elevated 1m to ensure the performer had clear visibility of the time frame. The scoreboard reset the timer automatically after the 15 seconds seized, however the participant could not begin the next trial until the timer had reset, regulating one attempt every 15 seconds. For a detailed diagram and further explanation of the entire testing area see Appendix B.

Participants were required to dress in tight, black attire including a sleeveless t-shirt to enhance evaluation of the required movement components. The experimenter attached six fluorescent kinematic markers (diameter= 5cm, see Appendix C*) for description)* to six specific locations on the right side of the participant's body. The markers attached to Under Armour Sweatbands (Baltimore, Maryland) were placed directly on the participant's epidermis (except #4 & 6) to best isolate these locations: 1. Ulnar styloid process, 2. Humerus lateral epicondyles, 3. Humerus great tubercle, 4. Femurs great trochanter, 5. Femurs lateral epicondyles, and 6. Fibulas lateral malleolus (adapted from Okazaki & Rodacki, 2012, see Appendix C). These markers provided the experimenter with specific movement information needed to accurately assess the movement quality of the jump shot. The participant and markers were recorded through a digital video camera (Canon VIXIA HV40). The camera was mounted on a tri-pod located at a sagittal distance of 8m to the right of the participant (Okazaki & Rodacki, 2012) with a height of 1.5m (Wulf et al., 2005). Movement of these markers were edited and analyzed using the Dartfish computer software program (Dartfish, Canada), which allowed the experimenter to isolate and track the motion of the markers. This interaction aided the experimenter in analyzing each specific trial to ensure that the appropriate jump shot technique was being facilitated. All videos (both instructional and condition specific model demonstrations), as well as computer-based questionnaires (and responses) were controlled by E-Prime 2 software (Sharpsberg, PA). The model demonstrations were viewed on a Dell OptiPlex GX620 desktop with a 19" (36 cm x 36 cm) liquid display monitor, which was located in the 'Observation Area' (4m to the back and right of the foul line). All other paper-based questionnaires were also administered and completed in the previously mentioned 'Observation Area' (see Appendix B).

The demonstrative model was a third-year varsity basketball point guard (height= 180 cm, arm reach = 95cm), and considered an expert in basketball. An expert is one who exhibits exceptional performance and takes a minimum of ten years of intense practice to achieve this level. They exhibit common performance characteristics in their use of vision and in knowledge of structures, which provides them the basis for exceptional performance capability (Magill, 2001). Thus, since the model played basketball 13 years of competitive basketball, and was the current starting point-guard on the university varsity team, he was labelled an expert in basketball. The model was video-recorded using the aforementioned camera dimensions and was filmed in an identical environment to that of the participants (varsity basketball court). The instructional videos consisted of the model (with the kinematic markers) demonstrating the proper jump shot technique according to the seven biomechanical teaching points (Knudson, 1993), and the two experiment-specific movement phases (coordination, release). The instructional video was viewed by participants prior to the commencement of any physical practice (Weeks & Anderson, 2000). Each video was identical in regards to the video footage being displayed (only 1 jump shot), however each of the videos contained unique movement information (visual) that was essential for properly understanding the jump shot technique. The instructional video isolated each of the seven biomechanical components by first displaying a screen containing a verbal description of the biomechanical component, followed by a video (50% speed, Scully & Carnegie, 1998) of the expert model demonstrating that specific biomechanical component, with the appropriate Dartfish (Calgary, CA) analytical information. The instructional video isolated and demonstrated the two segmented skill phases of the basketball jump shot utilizing the same presentation format that the previous biomechanical components were exhibited through (verbal description, expert model presentation). The following section provides a detailed description explaining the series of video that was viewed during the instructional phase of the experiment.

It is important to note that each video within the instructional package was the same footage of a single basketball jump shot attempt, and that all the video footage was presented in a slow-motion speed setting (50% speed). The instructional package included eleven separate videos demonstrating unique movement information in terms of basketball jump shot technique.

The following chart will describe the format to the instructional video:

Table 1.

Order of Instructional Video Demonstrations

Order	**Time Duration (seconds)**	**What the Model is Demonstrating**
1	20	Entire jump shot (no movement information)
2	10	*Coordination Component***1** (Staggered Stance)
3	10	*Coordination Component* **2** (Vertical Jump)
4	10	*Coordination Component***3** (Aligned Shooting Plane)
5	10	*Coordination Component*4 (Coordination Upper & Lower Extremities)
6	20	**All Coordination Components (1,2,3) in unison**
7	10	*Release Component* **1** (Optimized Height of Release)
8	10	*Release Component* **2** (Optimized Angle of Release)
9	10	*Release Component* **3** (Ball Rotation/Backspin)
10	20	**All Release Components (1,2,3) in unison**
11	20	Entire jump shot (no movement information)

To see how each video isolated the biomechanical component using Dartfish software, see Appendix D

It is important to note that each video demonstration did not show the success of the model's jump shot attempt to ensure that only the optimal jump shot technique was being demonstrated (Wulf et al., 2005).

All participants were informed they were going to be analyzed on their performance technique and shot accuracy. However, shot success was not the primary measure of skill acquisition; therefore, they were instructed to concentrate on their technique and accuracy, but not on accuracy at the expense of technique (Wulf et al., 2005). The experimenter assessed the shooting accuracy after all testing phases had ended utilizing the scoring method adopted from Wulf and colleagues, (2005, see Appendix F), these scores were:

Table 2.

Accuracy score rubric (Adopted from Wulf et al., 2005)

Accuracy Score	**Accuracy Description**
5 points	"Swish" -successful shot without the interaction of the rim and backboard
4 points	Successful shot regardless of interaction with rim and backboard
3 points	Unsuccessful shot, ball interacted with rim
2 points	Unsuccessful shot, ball interacted with rim and backboard
1 point	Unsuccessful shot, ball interacted only with the backboard
0 point	"Air-ball" unsuccessful shot, no interaction

The seven components that were used to analyze the jump shot technique were adapted from Knudson, (1993). Knudson identified six specific biomechanical components required to produce the optimal form (technique) of the basketball jump shot (see, Knudson, 1993). After initial piloting it was discovered that the first co-ordination component 'staggered stance & vertical jump' was comprised of two unique, unrelated motor actions. Thus, for the purpose of the present experiment the jump shot technique was comprised of seven motor components, four components have been defined as 'co-ordination' phase of the jump shot, and the other three components have been classified as the 'release' phase of the jump shot. The following is a summary of the seven biomechanical components and how they were be assessed by the experimenter, in regards to movement-form variation.

Table 3.

Technique component scoring rubric and descriptions (Adapted from Knudson, 1993)

Co-ordination Phase (Components)	**Description (Knudson, 1993)**
Staggered Stance	- A base of support slightly staggered with the shooting side foot forward.
Vertical Jump	-Minimize horizontal motion by jumping as close to the vertical as possible
Aligned Shooting Plane:	- Keep shooting side of body aligned with the basket and as close to the vertical as possible (shooting forearm lined up with the basket)
Co-ordination of Upper & Lower: Extremities:	- Integration of a controlled upper and lower body extremity action, without overreliance on either

Release Phase (Components)	Description (Knudson, 1993)
Optimized Height of release:	- Balanced jump, flexion of shoulder at release just prior to the peak of the jump (extend at the top of the jump)
Optimized Angle of Release:	- Shoot the ball 52 ° above the horizontal (shooting between 49-55 ensures a proper angle of entry and minimizes ball speed)
Ball Rotation:	- Typical 15 ft. shot will make 2 to 3 revolutions on the way to the basket

After all testing phases had ended; a researcher blind to the experiment collected, coded and then randomized the participant's video footage. The blind researcher then returned the randomized videos to the primary experimenter who analyzed and awarded a technique score ranging from 0-7 for each individual trial. The score was based on experimenter's ability to clearly recognize each of the seven components aforementioned during each trial, therefore a score of 1 was awarded if the component was clearly recognized, and if it was not clearly recognized the experimenter scored a 0. Thus, a perfect attempt was awarded a score of 7 (Adapted from Wulf et al., 2005). The experimenter spliced and edited each of the videos using Dartfish software (Dartfish, Canada), which produced two separate videos for each trial. The first video isolated the four co-ordination components of the basketball jump shot using Dartfish (Calgary, CA) software, while the second video isolated the three release components of the basketball jump shot (for sample images, see Appendix E). All questionnaire data was quantitative in nature and was entered by the experimenter on separate Excel files before being analyzed statistically utilizing SPSS analytical software (Armonk, NY).

3.3 Experimental Procedure

Upon arrival participants were asked to complete the ethical consent form and were debriefed on the testing area and procedure. The experimenter then measured and documented the height and right arm length of the participant followed by two paper and pen questionnaires: previous sporting experience and self-control capability (see, Appendix G, H, I respectively). The experimenter then guided the participant to the testing area in order to attach the kinematic markers on the six aforementioned locations. After the experimenter adjusted the markers and calibrated the camera (camera height and distance), the participant was directed to the center of the free throw line (testing area) where they were required to attempt 5 practice jump shots (pre-test 1). Once the first pre-test was completed, participants were directed back to the 'observational area' where they were presented an instructional video of the expert model demonstrating the proper jump shot technique.

Following the presentation of the instructional video, participants completed the first motivation questionnaire (adapted from Lewthwaite & Wulf, 2010, see Appendix J) as well as, a second, five-trial pre-test. Participants were asked to try and reproduce the jump shot technique recently demonstrated by the model. Upon completing the second pre-test, the participants were guided back to the 'observation area' where they were required to complete an online computerized assessment of their response perceived effort (RPE, Borg 1982, see Appendix K). The E-prime 2 computer program displayed a screen asking the participant to input a response (input 6-20) representing the level of physical exertion they felt while practicing the task during that specific block. A score of 6 (computer key "6") indicated "very very light" as a high score of '20' (computer keys

2+0) represented 'very very hard' (see, Appendix K). Also, dependent on their condition, participants may have been afforded the opportunity to view another demonstration of the expert model performing the jump-shot. Upon completion of each subsequent block, participants returned to the 'observation area', (excluding the final block) to complete the RPE questionnaire (15 seconds) and observe the additional modeled information (condition dependent).

After the participant completed the final block of five trials (block 10), they were required to complete the second motivation questionnaire (Lewthwaite & Wulf, 2010, see Appendix J*).* All participants returned exactly 24-hours later to perform a retention test consistent of ten trials (2 blocks), with no modeled information, followed by the RPE questionnaire, a recall questionnaire as well as the third adapted motivation questionnaire (Lewthwaite & Wulf, 2010). The recall questionnaire required the participants to list the seven biomechanical components necessary for facilitating the proper jump shot technique (Knudson, 1993; see Appendix L). The purpose of the recall questionnaire was to verify that the participant understood the biomechanical components encompassing the technique of the basketball jump shot. The recall questionnaire was utilized to establish whether there was a disconnect between understanding the skill cognitively and performing it motorically.

For participants in the SELF-CONTROL condition, the observation phase presented four options to choose from. The first option (computer key 1) resulted in a slow-motion video of the model performing the co-ordination phase of the basketball jump shot (15 seconds), followed by a blank white screen that displayed for 15 seconds. Selecting option two (computer key 2) resulted in the display of a blank white screen (15 seconds) followed by a slow-motion video of the model performing the release phase of the basketball jump shot (15 seconds). Selecting the third option (computer key 3) provided the participant with a slow-motion video of the model demonstrating the entire basketball jump shot (whole model: co-ordination & release phases, 30 seconds). Lastly, selecting option four (computer key 4) resulted in a blank white screen that was displayed for 30 seconds before it alerted the participant to return to the testing area.

The YOKED condition replicated each ‘observation phase’ of their SELF-CONTROLLED counterpart, yet without the choice. The purpose of the YOKED condition was to determine whether providing the learner choice over the frequency and content of the modeled presentation (i.e., SELF-CONTROL) would produce superior learning effects, compared to a pre-determined observation schedule (i.e., YOKED condition). Each participant in the YOKED condition was presented the modeled information (if any) his or her SELF-CONTROL counterpart chose during that specific ‘observation phase’. The CONTROL group followed the same procedure as the other conditions in regards to all physical testing components. However, when the CONTROL participants were in ‘observation phase’, and after they had answered the RPE questionnaire, the E-prime 2 program displayed a blank white screen on the computer monitor for 30 seconds, followed by a display directing the participant to return to the testing area. The reason why the control condition was presented a blank white screen (30 seconds) during each observation phase was to provide a temporal consistency amongst all conditions. Since this skill requires full body engagement, fatigue may have affected both the participant’s form and accuracy results. Thus, providing a temporal consistency for each participant in each condition during the observation phase (30 seconds.), helped control and alleviate any potential effect fatigue may have induced. This control condition was used as a comparative measure to understand the magnitude of skill acquisition as a result of model demonstrations (see Appendix M, for a detailed flowchart of testing procedure)

3.4 Data Analysis

In order to account for initial individual differences, two covariates were controlled for when completing the statistical analyses of the results. These covariates were the participant's height (cm) as well as the participant's right arm reach (cm). To examine the SELF-CONTROL learner's frequency of model demonstration requests a 4 (model option: Whole model, Coordination components, Release components, No Model) x 10 (Block) repeated measures – analysis of variance (RM-ANOVA) was utilized. The differences in jump shot technique scores between the conditions were analyzed in three separate time instances: Pre-Tests, Acquisition, & Retention. The pre-tests technique score differences were analyzed using a 3 (group: SELF-CONTROL, YOKED, CONTROL) x 2 (Pre-Test: 1 & 2) repeated measures analysis of variance (RM-ANOVA). The acquisition technique score differences were analyzed using a 3 (group: SELF-CONTROL, YOKED, CONTROL) x 10 (Block) repeated measures analysis of variance (RM-ANOVA). The retention technique score differences were analyzed using a 3 (group: SELF-CONTROL, YOKED, CONTROL) x 1 (Retention) analysis of variance (ANOVA).

The differences in jump shot accuracy scores between the conditions were analyzed in three separate time instances: Pre-Tests, Acquisition, & Retention. The pre-tests accuracy score differences were analyzed using a 3 (group: SELF-CONTROL, YOKED, CONTROL) x 2 (Pre-Test: 1 & 2) repeated measures analysis of variance (RM-ANOVA). The acquisition accuracy score differences were analyzed using a 3 (group: SELF-CONTROL, YOKED, CONTROL) x 10 (Block) repeated measures analysis of variance (RM-ANOVA). The retention accuracy score differences were analyzed using a 3 (practice condition: SELF-CONTROL, YOKED, CONTROL) x 1 (Retention) analysis of variance (ANOVA).

The difference in recall success scores between the conditions was analyzed using a (group: SELF-CONTROL, YOKED, CONTROL) x 1 (Recall Success of the seven components) analysis of variance (ANOVA).

The motivation questionnaires administered pre-acquisition, post-acquisition & post-retention were analyzed together to determine the difference in motivation from the three separate identifiable time instances. The motivation questionnaires were analyzed using a 3 (group: SELF-CONTROL, YOKED, CONTROL) x 3 (motivation check: pre-acquisition, post-acquisition, post-retention) analyses of variance with repeated measures on the last factor (RM-ANOVA).

All statistical analyses were conducted using the commercially available software Statistica version 7.0 by StatSoft Inc. For all statistical analyses, $p < .05$ was used as the alpha level, and Tukey's honest significant difference post hoc analysis was used to analyze any statistically significant interactions. Partial eta squared (η^2) was used as a measure of effect size.

CHAPTER FOUR

4.0 RESULTS

4.1 Frequency of Model Demonstrations (MD) requests during acquisition

The frequency of requested model demonstrations (MD) during the acquisition period are located on the left side of Figure 1. Overall, the SELF-CONTROL condition requested the MD on 90.8% of the acquisition trials. Furthermore, when the SELF-CONTROL condition requested the model demonstrations they specifically requested the *co-ordination* component on 25% of the acquisition trials, the *release* component on 25% of the acquisition trials and the *whole model* component on 40.8% of the acquisition trials.

During the acquisition period (blocks 1-10), participants in the SELF-CONTROL condition requested MD on 100%, 100%, 100%, 91.7%, 66.7%, 91.7%, 91.7%, 100%, 91.7%, and 75% of the acquisition blocks respectively. For the MD trials, the SELF-CONTROL condition selected the *co-ordination* component on 25%, 33.3%, 33.3%, 25%, 16.7%, 25%, 41.7%, 25%, 8.3%, and 16.7% of the acquisition blocks respectively. The *release* component was selected on 8.3%, 33.3%, 41.7%, 25%, 25%, 23%, 33.3%, 25%, 33.3%, and 0% of the acquisition blocks respectively. While the *whole model* component was selected on 66.7%, 33.3%, 25%, 41.7%, 25%, 41.7%, 16.7%, 50%, 50%, and 58% of the acquisition blocks respectively. Finally, the no model option was only selected on block 4 (8.3%), block 5 (33.3%), block 6 (8.3%), block 7 (8.3%), block 9 (8.3%), and block 10 (33.3%).

The effect of block on model option was examined by conducting a 4 (model option: No Video, Whole Model, Co-ordination components, Release components) x 10

(Block) RM-ANOVA. The ANOVA did not reveal a statistically significant main effect for model option F (9, 110) = 1.59, p = .13.

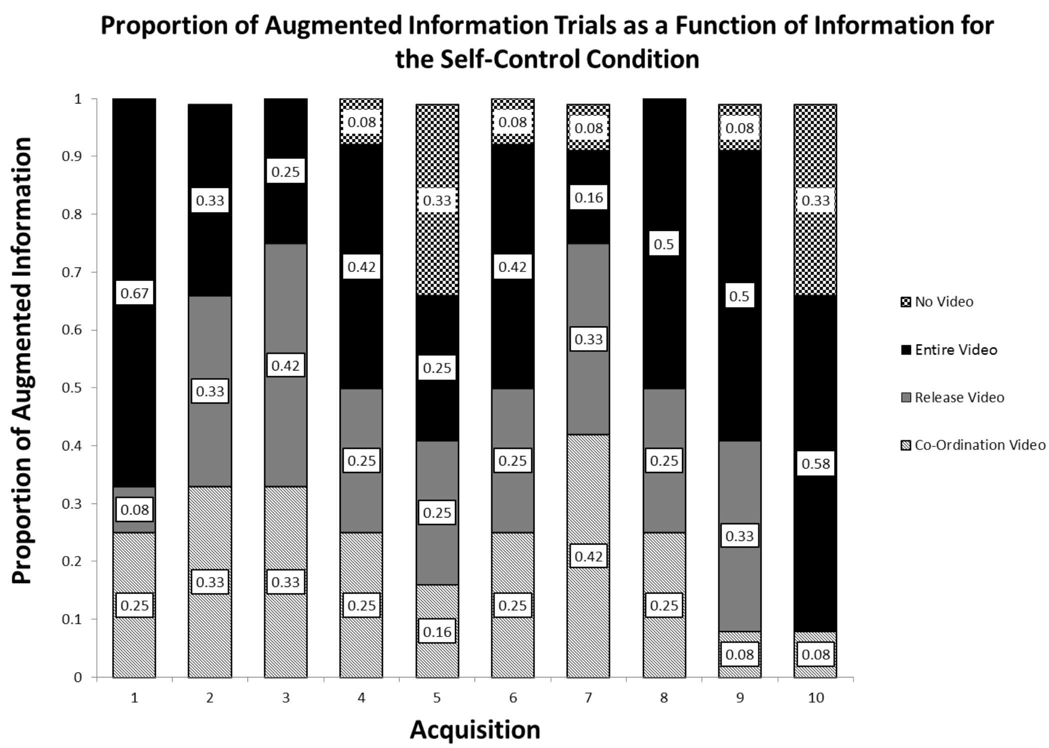

Figure 1. The proportions of 'model option' requested on MD trials during acquisition by the self-control condition.

4.2 Technique

The block means for all experimental conditions' technique scores during acquisition and retention periods are displayed on Figure 2.

4.2.1 Pre-Test 1 & 2

A 3 (group: SELF-CONTROL, YOKED, CONTROL) x 2 (Pre-test:1 & 2) RM-ANOVA was utilized to measure potential changes in technique as a function of pre-test (Pre-test 1= no instruction, Pre-Test 2= video instruction). The ANOVA showed a main effect for pre-test F (1, 33) = 85.9, p = .000, η_p^2 = .72. However, the interaction between pre-test and condition, F (2, 33) = .28, p = .76 was not statistically significant. A Tukey post-hoc test for the main effect showed that pre-test 2 (*M*= 3.29, *SE*= .12) was completed with greater technique than pre-test 1 (*M*= 1.82, *SE*= .15; p = .000).

4.2.2 Acquisition

The 3 (group: SELF-CONTOL, YOKED, CONTROL) x 10 (Block) RM-ANOVA showed a main effect for block F (9, 25) = 6.46 p = .000 η_p^2 = .70. The post-hoc analysis showed that block 4 was completed with better technique than block 1; block 7 was performed with better technique than blocks 1 & 5; blocks 8, 9 & 10, were all performed with better technique than blocks 1 through 7. The ANOVA also showed a statistically significant main effect for group F (2, 33) = 9.90 p =. 000 η_p^2 = .38. Post-hoc analysis revealed that the SELF- CONTROL group (*M*= 4.40 *SD*= .17) demonstrated superior technique acquisition compared to the YOKED (*M*= 3.53 *SD*= .17) and CONTROL (*M*= 3.42 *SD*= .17) groups, respectively. There were no statistically significant differences between the YOKED (*M*= 3.53 *SD*= .17) and CONTROL (*M*= 3.42 *SD*= .17) groups. The group by block interaction was not statistically significant, F (18, 52) = 1.40 p = .17.

4.2.3 Retention

The 3 (group: SELF-CONTOL, YOKED, CONTROL) x 1 (Retention test block) ANOVA revealed a main effect for group, F (2, 33) = 23.21 p = .000 η_p^2 = .59. The post hoc analysis indicated that the SELF-CONTROL group (*M*= 5.13, *SD*= .68) performed retention with superior technique compared to the YOKED (*M*= 3.93, *SD*= .62) and

CONTROL (*M*= 3.33, *SD*= .68) groups, respectively. The YOKED (*M*= 3.93, *SD*= .62) and CONTROL (*M*= 3.33, *SD*= .68) groups did not significantly differ.

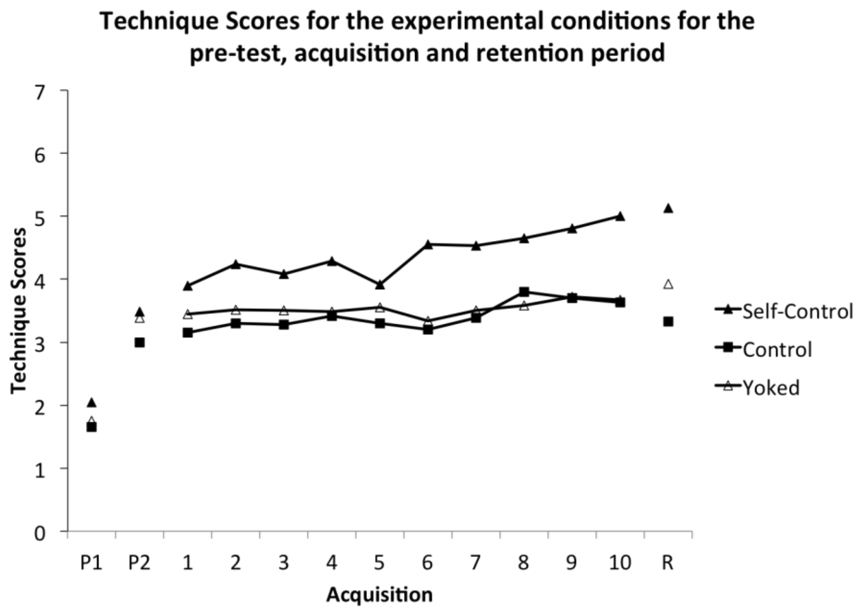

Figure 2. The *technique scores* for all experimental conditions across the Pre-tests', Acquisition and Retention periods

4.3 Accuracy

The block means for all experimental conditions' accuracy scores during acquisition and retention periods are displayed on the left side of Figure 3.

4.3.1. Pre-Test 1 & 2

A 3 (group: SELF-CONTROL, YOKED, CONTROL) x 2 (Pre-test:1 & 2) RM-ANOVA was utilized to identify any main effects or interactions as a function of pre-test (Pre-test 1= no instruction, Pre-Test 2= video instruction) and practice condition. Results did not reveal a statistically significant main effect for pre-test F (1, 33) = .04, p = .84; or a statistically significant interaction between pre-test and condition, F (2, 33) = .01, p = .99.

4.3.2. Acquisition

A 3 (group: SELF-CONTOL, YOKED, CONTROL) x 10 (Block) RM-ANOVA showed no statistically significant main effect for group F (2, 33) = .42 p = .66. Thus, the SELF-CONTROL group (M= 2.75 SD= .19) produced similar accuracy results as the YOKED (M= 2.6 SD= .19) and the CONTROL (M= 2.5 SD= .19) groups during practice. However, there was a main effect for block, F (5.89, 194.61) = 3.21 p=. 005 η_p^2 = .89. Mauchly's test of sphericity indicated that the assumption of sphericity was violated; therefore the degrees of freedom were adjusted using the Greenhouse-Geisser correction (Fields, 2004). Post-hoc analysis showed that block 4 was performed with more accuracy than block 3; block 5 was performed with more accuracy than block 4; Block 6 was performed with more accuracy than blocks 1, 2, 3 and 5; block 7 was performed with more accuracy than block 6; block 8 was performed with more accuracy than blocks 6 and 4. Block 9 was performed with more accuracy than blocks 3, 5, and 8; while block 10 was performed with more accuracy than blocks 5 and 8. The group by block interaction was not statistically significant F (11.79, 194.61) = .41 p = .96.

4.3.3. Retention

The 3 (group: SELF-CONTOL, YOKED, CONTROL) x 1 (Retention) ANOVA revealed a statistically significant main effect for group F (2, 33) = 6.36 p = .005 η_p^2 = .23, indicating the SELF-CONTROL (M= 3.1, SD= .44) and the YOKED (M= 2.9, SD= .73) groups had significantly greater accuracy scores when compared to the CONTROL group (*M*= 2.3, *SD*= .56) in retention. However, the SELF-CONTROL (*M*= 3.1, *SD*= .44) and the YOKED (*M*= 2.9, *SD*= .73) groups did not significantly differ.

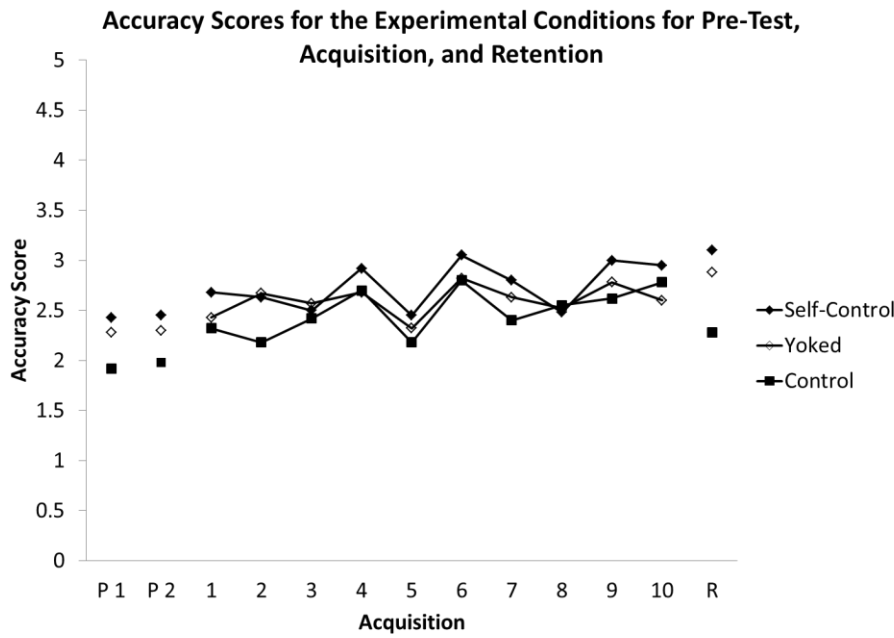

Figure 3. The *accuracy scores* for all experimental conditions across the Pre-tests', Acquisition and Retention periods

4.4 Proportion of Technique Components Performed & Acquired

In order to further analyze the participant's acquisition of the basketball jump shot, technique was divided into two sub-categories: co-ordination components & release components. The block means for both co-ordination & release scores for all experimental conditions across the acquisition and retention periods are displayed on Figure 4.

4.4.1 Co-ordination Pre-Test 1 & 2

A 3 (group: SELF-CONTROL, YOKED, CONTROL) x 2 (Pre-test:1 & 2) RM-ANOVA was utilized to measure any effects or interactions present as a result of completing two pre-tests (Pre-test 1= no instruction, Pre-Test 2= video instruction). Results did reveal a statistically significant main effect for pre-test F (1, 33) = 46, p = .000, η_p^2 = .58. A Tukey post-hoc follow-up test was conducted to identify the differences for Pre-Test. Post-hoc analysis revealed that pre-test 2 (*M*= .53, *SE*= .17) was completed with greater co-ordination technique than pre-test 1 (*M*= .26, *SE*= .2; *p*= .000). The results also revealed no statistically significant interaction between pre-test and condition, F (2, 33) = .13, p = .88.

4.4.2 Release Pre-Test 1 & 2

A 3 (group: SELF-CONTROL, YOKED, CONTROL) x 2 (Pre-test:1 & 2) RM-ANOVA was utilized to measure any effects or interactions present as a result of completing two pre-test (Pre-test 1= no instruction, Pre-Test 2= video instruction). Results did reveal a statistically significant main effect for pre-test F (1, 33) = 55.7, p = .000, η_p^2 = .63. A Tukey post-hoc follow-up test was conducted to identify the differences for Pre-Test. Post-hoc analysis revealed that pre-test 2 (*M*= .23, *SE*= .15) was completed with greater release technique than pre-test 1 (*M*= .08, *SE*= .13; *p*= .000). The results also revealed no statistically significant interaction between pre-test and condition, F (2, 33) = 1.2, p = .8832.

4.4.3 Co-ordination Acquisition

A 3 (group: SELF-CONTOL, YOKED, CONTROL) x 10 (Block) RM- ANOVA showed a statistically significant main effect for block, F (5.23, 297) = 2.29 *p*=. 045 η_p^2 =

.07. Mauchly's test of sphericity indicated that the assumption of sphericity was violated; therefore the degrees of freedom were adjusted using the Greenhouse-Geisser correction (Fields, 2004). Post-hoc analysis revealed that blocks 4, 8 & 10 were performed with more co-ordination technique than blocks 5 & 6. Blocks 8 & 10 were performed with more co-ordination technique than block 2; block 9 was performed with more co-ordination technique than block 6. The analysis also revealed a statistically significant main effect for group F (2, 33) = 10.13 p=. 000 η_p^2 = .38. Post-hoc analysis revealed that the SELF-CONTROL (M=.73, SE= .04) group had greater co-ordination scores than both the YOKED (M= .50, SE= .04) and CONTROL (M= .52, SE= .04) groups. However, the YOKED (M= .50, SE= .04) and the CONTROL (M= .52, SE= .04) groups did not significantly differ. The group by block interaction was not statistically significant F (10.45, 297) = 1.27 p = 25.

4.4.4 Release Acquisition

A 3 (group: SELF-CONTOL, YOKED, CONTROL) x 10 (Block) RM-ANOVA showed a statistically significant main effect for block, F (6.01, 297) = 8.36 p=. 000 η_p^2 = .20. Mauchly's test of sphericity indicated that the assumption of sphericity was violated; therefore the degrees of freedom were adjusted using the Greenhouse-Geisser correction (Fields, 2004). Post-hoc analysis revealed that blocks 2-9 were performed with superior release technique than block 1. Block 7 was performed with superior release technique than block 3; blocks 8, 9, & 10 were performed with greater release technique than blocks 2, 3, 4, & 5; block 9 was also performed with superior release technique compared to blocks 6 & 7. The analysis did not reveal a main effect for group F (2, 33) = 1.72 p=. 20.

The group by block interaction was statistically significant F (12.01, 297) = 1.97 p = 03 η_p^2 = .11. However, the Tukey post-hoc test was not able to detect any differences.

4.4.5 Co-ordination Retention

The 3 (group: SELF-CONTOL, YOKED, CONTROL) x 1 (Retention) ANOVA revealed a statistically significant main effect for group F (2, 33) = 13.5 p = .000 η_p^2 = .45, indicating that the SELF-CONTROL (*M*=.80, *SD*= .1) group had significantly greater coordination technique scores compared to the YOKED (*M*= .55, *SD*= .14) and CONTROL (*M*= .50, *SD*= .19) groups in retention. However, the YOKED (*M*= .55, *SD*= .14) and the CONTROL (*M*= .50, *SD*= .19) groups did not significantly differ from each other.

4.4.6 Release Retention

The 3 (group: SELF-CONTOL, YOKED, CONTROL) x 1 (Retention) ANOVA revealed a statistically significant main effect for group F (2, 33) = 8.02 p = .001 η_p^2 = .33, indicating that the SELF-CONTROL (*M*= .61, *SD*= .23) and the YOKED (*M*= .42, *SD*= .22) groups had significantly greater release technique scores compared to the CONTROL group (*M*= .29, *SD*= .14) in retention. However, the SELF-CONTROL (*M*= .61, *SD*= .23) and the YOKED (*M*= .42, *SD*= .22) groups did not significantly differ, nor did the YOKED (*M*= .42, *SD*= .22) and CONTROL (*M*= .29, *SD*= .14) groups.

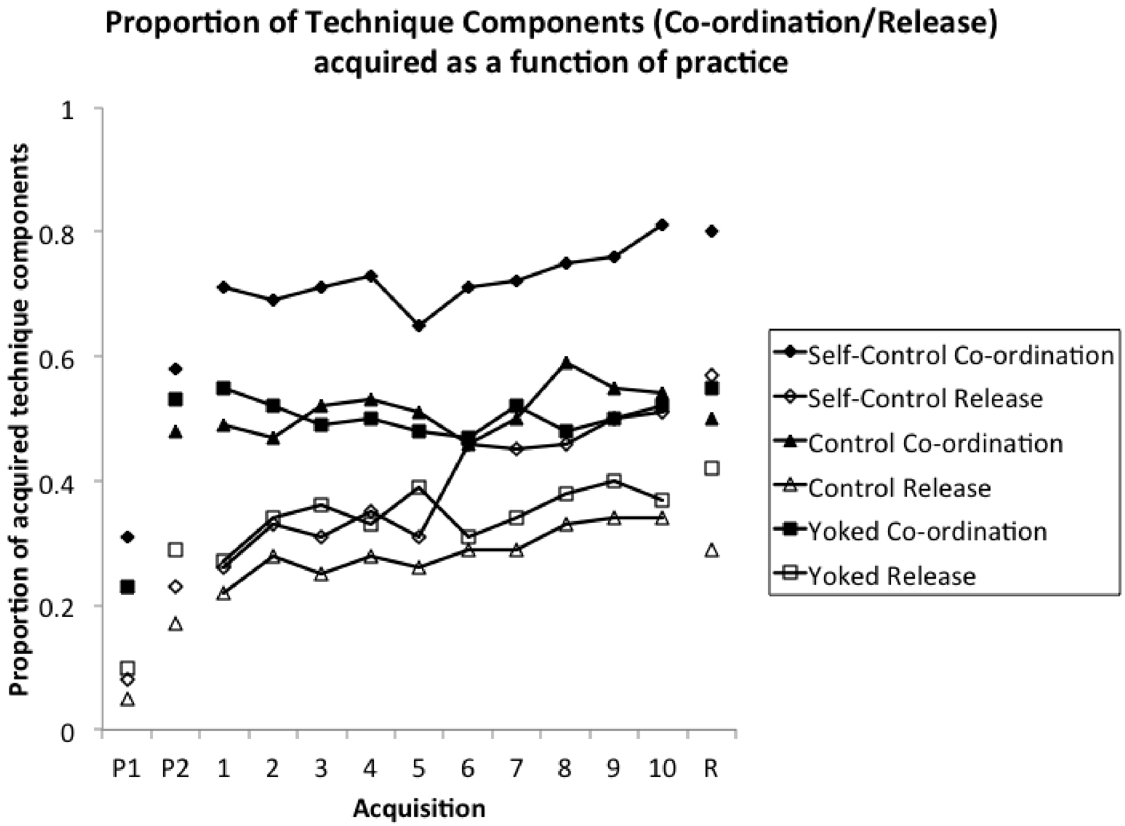

Figure 4. Proportion of acquired technical components (co-ordination/ release) during the pre-test, acquisition and retention testing phases.

4.5 Components of Technique Acquired During Practice (Self-Control)

In order to assess the SELF-CONTROL condition's efficiency on the technique components (co-ordination/release) acquired across practice a 2 (co-ordination, release) x 10 (block) RM –ANOVA was conducted. Mauchly's test of sphericity indicated that the assumption of sphericity was violated; therefore the degrees of freedom were adjusted using the Greenhouse-Geisser correction (Fields, 2004). Results indicated a statistically significant interaction for component x block F (4.99, 109.69) = 2.72 p = .024 η_p^2 = .11. Tukey's post-hoc test revealed that for co-ordination component, block 10 was performed with significantly superior co-ordination technique than block 5. The post-hoc test also revealed that for the release component blocks 6 through 10 did not significantly differ from one another but were all performed significantly better than block 1. Blocks 6, & 8, were performed with significantly greater release technique than blocks 3, & 5, while blocks 9, & 10 were both performed with greater release technique than blocks 2-5 (Figure 5).

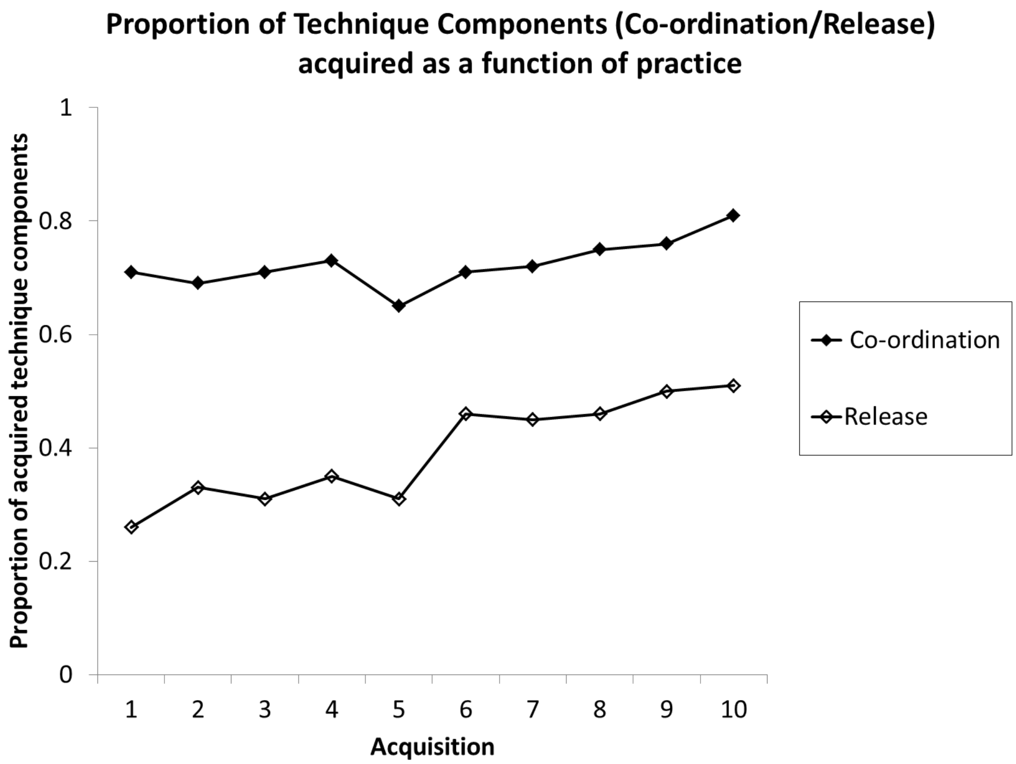

Figure 5. Proportion of acquired technique components (co-ordination/ release) during acquisition for the SELF-CONTROL condition.

4.6 Recall Success

In order to assess the explicit memory of the cognitive representation of the biomechanical technique components, a recall success test was utilized. The means for recall success scores for all experimental conditions are displayed on the left side of Figure 6. The 3 (group: SELF-CONTOL, YOKED, CONTROL) x 1 (Recall Success score) ANOVA revealed a main effect for group, F (12, 33) = 3.54 p =.04 η_p^2 = .18. Post hoc analysis revealed that the SELF-CONTROL (M=.79 SD= .19) group significantly recalled more the modeled components compared to the YOKED (M= .57 SD= .24) group. However, the SELF-CONTROL (M=.79 SD= .19) group did not significantly differ from the CONTROL (M= .61 SD= .22) group nor did the YOKED (M= .57 SD= .24) group from the CONTROL (M= .61 SD= .22) group (see Figure 6).

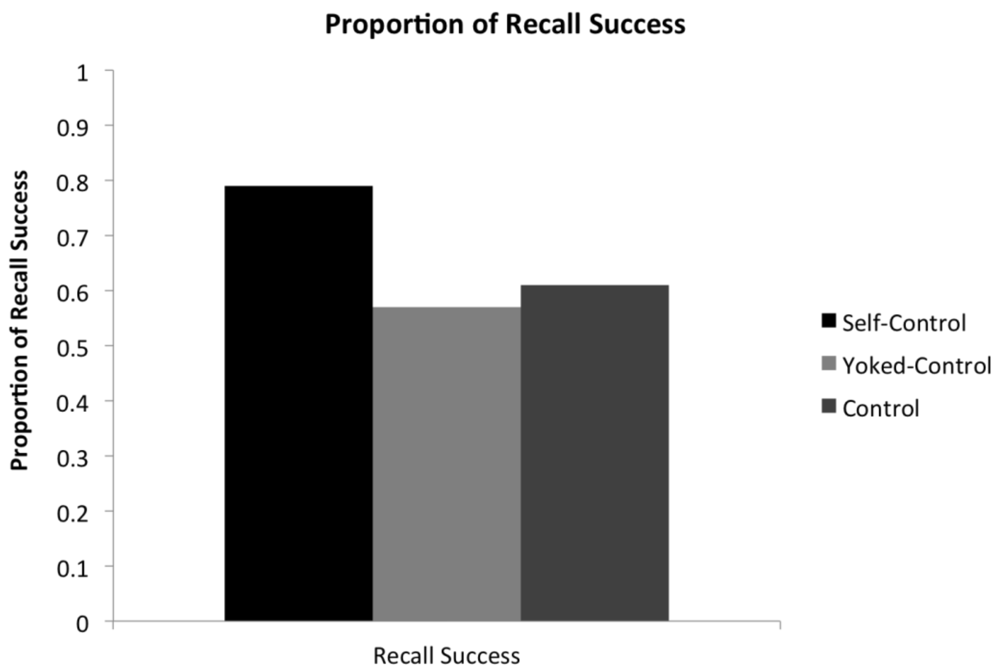

Figure 6. The proportion of *recall success scores* for all experimental conditions

4.7 Motivation

The means for the motivation scores for all experimental conditions are displayed on the left side of figure 7. The 3 (group: SELF-CONTOL, YOKED, CONTROL) x 3 (motivation checks: before practice, after practice, before retention) RM-ANOVA revealed statistically insignificant main effects for group F (2, 33) = .045, p = .96.

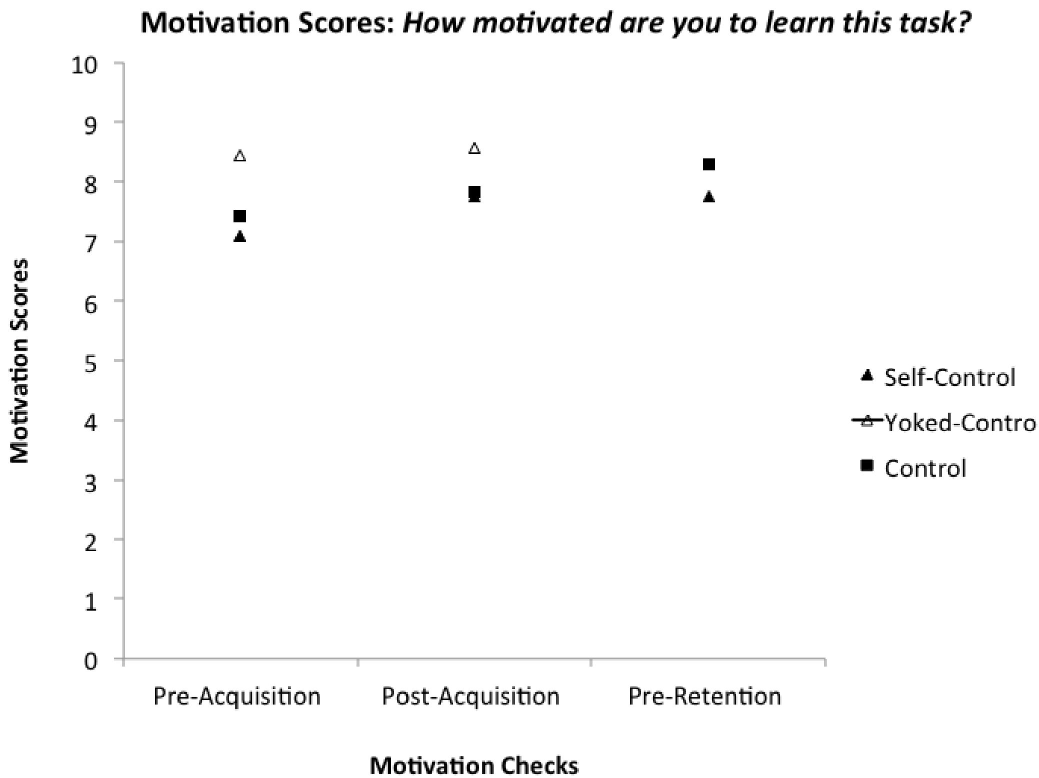

Figure 7. The *motivation check scores* for experimental conditions

4.8 Anthropometric, Self-Control, Previous Sport Experience, and RPE Results

Each participant's height and right arm length was taken at the beginning of the acquisition phase. Results indicated that the height and arm length group means were statistically similar (see appendix G) and that they did not correlate with any of the dependent variables. Participants were also required to report their previous self-control and sport experience prior to being tested (see Appendices H & I, respectively). Results indicated that neither the groups' self-control abilities, nor their previous sport experiences correlated with any of the dependent variables and subsequent results. Lastly although the RPE measures were taken periodically throughout practice, no single participant reported a RPE score higher than 9 of 20. Thus, these RPE scores were not further analyzed.

CHAPTER FIVE

5.0 Discussion

The purpose of the present experiment was two-fold. The first purpose was to examine the effects of self-controlled video augmented information (segmented vs. whole model demonstration) on the acquisition of the basketball jump shot by novices. It was predicted the **accuracy** and **technique** of the basketball jump shot would be superior for the participants who were given the opportunity to choose and observe the videos of the modeled jump shot technique (i.e., self-control) compared to those who were not afforded choice (i.e., yoked) or no observation of the model demonstration (i.e., control condition). It was also predicted that those afforded control of the selection and observation of the model demonstrations would develop a stronger cognitive representation of the task (assessed via **recall success**) compared to those not afforded control over choice and observation of the model demonstrations. This means the self-control condition would recall more of the motor skill's technique components compared to the yoked and control conditions (Patterson & Lee, 2010). Additionally, it was predicted those who had control of choosing and observing the model demonstrations (i.e., self-control) would report higher **motivation**-to-learn scores than those not afforded choice (i.e., yoked) or observation (i.e., control). Therefore, the self-control condition would have superior accuracy, technique, recall success, and report higher-motivation compared to the yoked and control conditions, during all experimental phases (i.e., acquisition and retention). These predictions are based on the findings from both the self-control and observational literature, where controlling the frequency (i.e., self-control) of augmented information was advantageous in the motivation-to-learn (Chiviacowsky & Wulf, 2002, 2005;

Chiviacowsky et al., 2008; Hansen, Pfeiffer, & Patterson, 2011) as well as the motor acquisition (technique & accuracy) of a novel motor skill (Andrieux et al., 2012; Brydges, Carnahan, Saif, & Dubrowski, 2009; Brydges, Carnahan, Rose, & Dubrowski, 2010; Bund & Wiemeyer, 2004; Chviacowsky et al., 2008a, 2008b; Hodges, Edwards, Luttin, Bowcock, 2011; Janelle et al., 1995, 1997; Jowett, LeBlanc, Xeroulis, MacRae, & Dubrowski, 2007; Post, Fairbrother, & Barros, 2011; Wrisberg & Pein, 2002; Wu & Magill, 2011; Wulf et al., 2005). The results of the present study provided partial support for these predictions. In regards to accuracy of the jump shot, the prediction was partially supported, while the prediction for technique of the jump shot was fully supported. Additionally, the prediction for recall success of the jump shot was partially supported, and the prediction of the participant's motivation to learn the task was not supported.

The second purpose of the present experiment was to examine whether there was a modification in learning strategy (evidenced via the frequency of choosing specific augmented observation information) of participants when afforded both the segmented and whole model demonstrations. Although this concept has yet to be directly measured in motor learning research, it was predicted that participants in the self-control condition would sample the segmented model demonstrations (release, coordination) more frequently than the whole model and no model demonstration. This prediction was based on the principles of the challenge point framework (Guadagnoli & Lee, 2004), whereby skill acquisition can be optimized via alterations to the tasks' functional difficulty. Specifically, by providing choice of which skill segments to observe, self-control participants had the opportunity to control the amount of interpretable movement information at one instance, and thus could develop an effective learning strategy (choice of augmented information) that promotes optimal cognitive and motor challenge.

5.1 Proportion of Choice

Research has shown that self-control learners utilize model demonstrations to pay more attention to components of the movement pattern they are uncertain about, either as a method of confirming that their movements are correct, or, to identify any errors in their movement (Wulf et al., 2005). However, these results are based on the observation of whole model demonstrations, not segmented (Wrisberg & Pein, 2002; Wulf et al., 2005). Thus, the second purpose of this research study was to determine whether the self-control participants would select the segmented model demonstrations more often than the whole model and no model video options. Due to the exploratory nature of this inquiry, and the tenets of the Challenge-Point Framework (Gudagnoli & Lee, 2004), it was speculated that the self-control participants would frequent the segmented model demonstrations more often than the whole model or no model options.

The results indicate that segmented model demonstrations were selected on 50% of the acquisition trials, while the whole model demonstration was only selected on 40.8% of the acquisition trials. Although the proportion of choice was not statistically different throughout practice speculations can be postulated based on the model demonstration block means. For example, the whole model demonstration was most viewed during the first (block 1) and latter (blocks 8, 9, 10) blocks of practice, perhaps to develop and refine the motor plan for successful skill reproduction. Meanwhile, throughout the majority of practice (blocks 2-7), the segmented skill demonstrations were most often selected, perhaps to acquire a deeper understanding of the skill’s technical components, and to correct errors in their individual motor response. This may suggest that when learners are given a choice for more specific movement information (i.e., segmented model demonstration) they utilize it to their learning advantage. In the confines of the Challenge Point Framework it appears that the functional difficulty of the task can be transformed (via observation of segmented skill components) to optimally challenge the learner's cognitive processes, without provoking information overload. Thus, due to the complexity of the task itself (nominal difficulty), segments of observational interpretable movement information were the preferred observation option of self-controlled learners during practice.

Although there were no statistically significant differences between which skill segment was selected most frequently (coordination- 50%, release -50%), the co-ordination segment mean were higher in the early blocks of practice (blocks 1-3), while the release segment means were higher in the later blocks of practice (blocks 8, 9). Thus, the co-ordination segment was perhaps selected more at the beginning of practice to develop the initial motor plan, while the release segment was perhaps selected more in the latter blocks practice to develop a deeper understanding of the success-oriented components, as well as to refine the motor output. Interestingly, the results also indicated that throughout the first blocks of practice (blocks 1-4), an average of 71% of the co-ordination components were being performed correctly, while only an average of 31% of the release components were being performed correctly. Meanwhile, in the latter blocks of practice (blocks 6-10), an average of 75% of the coordination components were being performed correctly, while an average of 48% of the release components were being performed correctly. It could be that perhaps that self-control learners selected the model segments according to what their technical goal was for that subsequent block ((i.e., observe the ‘release’ segment; elicit more effort in performing release components); see, Figure 4). Furthermore, upon selecting the segmented demonstrations, it could be that the self-control participants were more inclined to try and re-produce the components of the skill they just observed, therefore constantly challenging or refining both their cognitive and motor representations of the jump shot. Although this was not statistically evaluated it presents itself as an appropriate and valid speculation.

In summary, results indicated that when provided choice, self-control learners selected the segmented model demonstrations most frequently compared to the whole model and no model demonstration options throughout practice. However, future research needs to be conducted to determine the learning effects of those only provided segmented model demonstrations and those only provided whole model demonstrations in order to determine whether observation of segmented demonstrations are most effective for self-controlled learning efficiency.

5.2 Technique

One of the primary purposes of this experiment was to determine if self-controlled video augmented information (segmented vs. whole model demonstration) differentially effects the technique acquisition of the basketball jump shot. It was predicted that participants who were provided choice (i.e., self-control) of augmented video information would demonstrate superior jump shot technique compared to those not provided choice (Wrisberg & Pein, 2002; Wulf et al., 2005). Wulf and colleagues (2005), showed that participants demonstrated superior jump shot technique after viewing and controlling the frequency of whole model demonstrations, compared to those not provided control (yoked). Given that Wulf and colleagues (2005), only investigated the learning effects noted with whole model demonstrations, the current study extended this work by affording the choice to observe segmented model demonstrations (i.e., coordination vs. release), along with the choice for whole model demonstrations and no model demonstrations. Analysis of technique data indicated that those who were provided choice of segmented video demonstration observation (self-control) did in fact showcase superior technique scores during acquisition and retention, compared to those not afforded choice (yoked) or those not afforded model observation after the initial instruction (control). Thus, the experimental prediction for technique was supported. It is interesting to note that all conditions technique scores were statistically similar at the end of the first pre-test (initial skill level), second pre-test (after instruction video) and throughout blocks one to five (where Wulf & colleagues (2005), seized practice). Pre-test 2 was utilized for comparative measures because during the first pre-test participants may have been unaware of what an actual 'jump shot' was, which in turn could have provoked variation in their motor production, perhaps performing movements that were irrelevant to the skill (i.e., shooting underhand). Thus, by using the second pre-test all participants had a uniform understanding of what specific motor-movements define a jump shot, and how they can subsequently perform them. It wasn't until the latter half of practice (blocks 6-10), that the self-control participants amplified their technique score differences compared to the yoked, and control condition (F (2, 33) = 9.90 p =. 000 η_p^2 = .38). This statistical trend continued through retention where the self-control participants acquired 73% of the technical components, while the yoked, and control conditions acquired 56% and 48% of the technical components respectively (see Figure 2). These results indicate that self-controlling augmented information (video demonstrations) is an influential practice variable that enhances skill acquisition efficiency.

Existing research indicates that self-controlling a practice variable is an effective method in influencing learning efficiency. (i.e., Bund & Wiemeyer, 2004; Chiviacowsky & Wulf, 2002; Wrisberg & Pein, 2002; Wulf et al., 2005). Furthermore, controlling the frequency of modeled demonstrations has exhibited enhanced acquisition efficiency, especially when regarding technical skill acquisition (Wrisberg & Pein, 2002; Wulf et al., 2005). This is attributed to self-control participants being more conscious of their preparation for a motor response and subsequent interpretation of their motor response outcome (Andriuex et al., 2012). While in contrast, augmented information that is unpredictable (yoked), or absent (control) during practice, has been shown to hinder subject motivation as well as limit the engagement of information-processing activities that are necessary to effectively comprehend, and acquire the skill (Janelle et al., 1995; Wulf et al., 2005). Therefore, the results of the present study suggest that choosing (self-control) the model demonstration content (i.e., segments, whole model, no model), is the most advantageous practice method to learning the technique of a basketball jump shot. In contrast, receiving pre-determined augmented information during a task (yoked), or not receiving any information (control), are both inefficient methods of acquiring jump shot technique.

According to Guadagnoli and Lee's (2004), Challenge Point Framework, learning is related to the amount of interpretable task information available (i.e., whole vs. segmented), only when the individual's past experience is accounted for, and when the task's practice variables continuously challenge the learner (see, Guadagnoli & Lee, 2004 for review). Considering that the self-control condition could monitor the quantity of interpretable information (i.e., choose different segments on different blocks), they had the opportunity to optimally challenge their cognitive and motor capabilities throughout practice. The proportion of augmented information selected by the self-control condition during practice perhaps can best demonstrate this. It is important to note that mid-way through practice (block 5), and at the end of practice (block 10), the ‘no video’ option was the option with the highest mean indicating that the majority of the self-control participants utilized this ‘no model’ option as a method to challenge how accurate their interpretation and production of the observed skill was. Thus, choosing the ‘no model’ option was considered the highest level of challenge as the participants had to produce the motor action according to their cognitive representation established in previous blocks, and without the guidance of the model demonstration.

Additionally, as the Challenge Point Framework suggests, learning gained on a given trial is encompassed by the amount of information processed before, during, and after response execution (Andrieux et al., 2012; Magill, 2011; Schmidt & Lee, 2005). Therefore, with multiple sources of augmented information (i.e., whole vs. segmented) the participant’s action plan was constantly being modified and refined, which resulted in more efficient information-processing capabilities, and ultimately greater acquisition success. In contrast, since the information was pre-determined for the yoked condition, or not present for the control condition, participants had difficulty establishing a consistent action plan, in turn, increasing the functional difficulty of the task, which resulted in ineffective, inefficient technique acquisition. Therefore, it seems that providing learners with the ability to choose what information the model demonstration displays throughout practice, allows them the opportunity to freely adjust their observation strategy (i.e., choice to observe model segments), and “optimally challenge” themselves to reach skill proficiency (Andrieux et al., 2012; Guadagnoli & Lee, 2004).

An alternative interpretation of the technique results can be understood through Bandura’s (1969, 1977) social leaning theory. According to Bandura’s (1969, 1977) social learning theory, the attentional and retentional sub-processes are the most influential sub-processes in creating the cognitive representation of the observed skill. Essentially, an individual cannot learn much from simply observing a model demonstration if they don’t not attend to the essential features of the models behaviour (i.e., technique details, (Bandura, 1977)). As mentioned in previous research, the strength of the cognitive representation is defined by the ability to effectively code the stimuli observed (Bandura, 1971). Thus, the observational information needs to be detailed and concise. Research has demonstrated that multiple sources of task-related information (i.e., whole, segmented) are beneficial for complex tasks as they provide the necessary information for the development of a cognitive representation and facilitate overt performance (Adams, 1971; Baudry, Leroy, & Chollet, 2006; Hodges et al., 2003; Laguna, 2004; Tzetzis, Mantis, Zachopoulou, & Kioumourtzoglou, 1999). Logically, by segmenting the skill demonstration, learners were provided with more detailed specifications of the technique components which were necessary for jump shot acquisition, and which may have not noticed when observing the whole model demonstration. Thus, segmented demonstrations afford the learners greater opportunity to code this component-organized (e.g., coordination component, release component) augmented information, and embed the movement characteristics into their memory to develop a stronger cognitive representation (Bandura, 1977). Furthermore, possessing the ability to choose which skill segment to observe (if any), also aided in developing the learners cognitive representation of the skill, as they could arrange segment observation based on their individual acquisition progress.

Given that the self-control participants on average sampled each observation option (whole, coordination, release, no model) more than once (see, proportion of choice) it indicates that they were concentrating on different components of the skill as they strengthened their mental coding process. Perhaps, the self-control participants were more conscious during practice in developing an appropriate mental code of the technique components, and in analyzing how accurate their motor production was in accordance to their cognitive representation. When considering both the retention technique scores and the recall success scores for the self-control participants in this experiment, it can be noted that they demonstrated a statistically significant superiority in both motor and cognitive comprehension compared to their yoked counterparts and a statistically significant superiority in motor comprehension when compared to the control participants. Thus, the technique results add support to Bandura's (1969) social learning theory such that the utilization of self-controlled segmented skill demonstrations aids in the efficiency of the attentional and retentional sub-processes, which consequently influences the efficiency of the reproductional and motivational sub-processes of learning respectively. Future research should investigate whether dividing the segment choice into a sequential learning pattern (i.e., first 5 blocks: coordination segment, whole model, no model; last 5 blocks: release segment, whole model, no model) will provide the learner with a more structured motor plan and subsequent motor production.

5.3 Accuracy

Based on existing research, it was hypothesized that the self-control participants would demonstrate superior task accuracy compared to the other experimental conditions (yoked & control) during acquisition and retention (Andrieux et al., 2012; Bund & Wiemeyer, 2004; Chiviacowsky et al., 2008a, 2008b; Hodges et al., 2011; Janelle et al., 1995; 1997; Post et al., 2011; Wrisberg & Pein, 2002; Wu & Magill, 2011). The results of the present study partially supported this prediction. During acquisition there were no statistically significant differences between the groups, however the self-control condition demonstrated slightly greater accuracy scores throughout the progression of practice, compared to the yoked and control conditions. The results showed the self-control condition having statistically superior accuracy scores compared to the control condition, however they did not differ significantly from their yoked counterparts in accuracy retention scores (62%, 58% respectively). These findings are consistent with previous jump shot research (Wulf et al., 2005) who also found non-statistically significant jump shot accuracy score's differences between the self-control (57%) and yoked (51%) participant's during retention. The current results showed that the self-control and yoked conditions had statistically significant accuracy differences from the control condition in retention, however accuracy only increased (12.8%, 12%, respectively) from pre-test 2 to the retention test. Furthermore, no statistically significant accuracy score differences were found between the self-control, and yoked groups in retention. Thus, jump shot accuracy was acquired, but only as a function of consistent augmented information (model demonstration) observation throughout practice, not a function of self-controlling practice. It is evident that both the self-control and yoked conditions benefited from observing more frequent model demonstrations, while the control condition did not display improvements in accuracy.

One primary reason as to why the majority of the jump shot accuracy scores were relatively low throughout practice and retention for all participants was simply because the goal of the study was to complete the jump shot, concentrating on shot form and not shot success. The experimenter specifically stated at the beginning of each block to all participants “concentrate on shot form, not shot success.” This instruction set was repeated at the beginning of each physical practice block (Wulf et al., 2005), which could have influenced the participant’s learning strategy to focus primarily on the movement components and less about producing an accurate shot. However, given that the accuracy scores were low the results suggest that participants were adhering to their specific task instructions administered by the experimenter.

Another factor that could have influenced the participant’s accuracy scores was that the modeled video provided focused on the technique (shoulder alignment, angle of release) of a basketball jump shot, and not accuracy (the model demonstration ended before participant could view shot success). As a result, the video ensured that participants focused on the demonstration components that correlate with jump shot technique success (i.e., technique). The instructional video utilized in previous research (Wulf et al., 2005) modelled the jump shot from different angles and perspectives, but did not afford the learner the opportunity to view segments of the motor action. Thus, as a method to ensure that all participants in all conditions understood what was required for successful jump technique, the instructional video in the present research demonstrated each individual technique component, as well the jump shot in its entirety. Therefore, self-controlling segmented model demonstrations while being instructed to concentrate on technique during practice, seemingly compromised jump shot accuracy. Future research should investigate whether altering the instruction set to include concentration on jump shot accuracy, effectively influences jump shot accuracy acquisition. Also, future research should investigate when to introduce accuracy augmented information and when to introduce technique augmented information, as perhaps learners require comprehension of the skills technique components before refining task accuracy.

5.4 Recall Success

In the present research it was hypothesized that the self-control participants would significantly recall more components of the jump-shot technique compared to their yoked counterparts and the control participants. Recall success was measured once prior to the beginning of the retention test, whereby the participants were asked to physically write down the seven technical components of the basketball jump shot (Knudson, 1993). Results indicated that the self-control participants recalled an average of 79% of the technique components, while the yoked and control participants recalled an average of 57% and 61% of the technical components respectively (see Figure 6). Interestingly the self-control participant's recall success scores significantly differed from their yoked counterparts, but not from the control participants; while the control participants and yoked participants' recall success scores were statistically similar. Thus, this prediction was partially supported.

It is important to note that the present research study was the first of its nature (to our knowledge), to investigate the strength of the cognitive representation (biomechanical recall success) and the strength of the motoric representation (i.e., accuracy, technique) when acquiring a novel complex sport skill (basketball jump shot). According to the present results, the self-control condition recalled the most technique components during retention followed by the control and yoked conditions. The fact that the self-control participants were able to significantly recall more task information from their yoked counterparts is consistent with previous motor learning research (e.g., Patterson & Lee, 2010; Milne, Bordenave, & Patterson (November, 2012) Poster presented at the SCAPPS conference on Psychomotor Behavior, Halifax, NS). However, the recall success similarity between the self-control and controlled condition was unexpected.

Perhaps for the self-control condition, the enhanced recall success was based simply on the ability to control observation of task information (i.e., skill segments). By choosing the type of task information at each time point (i.e., choose segmented model) the self-control participants could elicit a deeper cognitive understanding of the relevant task information. This may have caused the participants to dissociate task information that was perceived to be easily learned (i.e., shooting foot forward) and task information that was perceived to be more difficult to learn (i.e., angle of release; Metcalfe & Finn, 2008). Considering the results for proportion of choice, self-control participants selected to observe the coordination segment most frequently during the early blocks of practice, and the release segment during the latter blocks (see Figure 1). Interestingly, although the yoked participants observed the exact same skill segments as their self-control counterparts, they were not in control of segment choice, and thus could not anticipate what information was going to be observed. Essentially through the yoked participants point of view they were being presented random model demonstrations (whole, segments), which in turn, impaired their ability to efficiently interpret, code, refine and rehearse task information, leading to poor cognitive retention of the technique information (recall success scores). Therefore, it is assumed that affording observation choice of modeled skill segments provokes the learners to elicit more effort into coding the demonstrated activities and retaining the modeled behaviour more efficiently than those who simply observe the model performance (Bandura, 1977).

Perhaps the most unexpected finding was the recall success scores for the control participants. Results indicated that the control condition was statistically similar in recalling the technique components to both the self-control and yoked conditions. Thus, suggesting that only viewing a detailed instructional video before practice, without further observation of augmented information (control) during the practice period is sufficient for developing a general cognitive representation of the motor skill, however not for the motor performance of the observed skill (i.e., technical scores). Perhaps the control condition's unique recall success scores can be attributed to the efficiency of their attentional and rententional sub-processes as a function of observing the instructional video without further observation of augmented information (Bandura, 1977). Due to the isolation of each individual technique component demonstrated in the instructional video, all participants were afforded the opportunity to establish a strong initial cognitive representation of what was required for shot success. Since the control participants were not provided any further video demonstrations, they perhaps continuously coded and rehearsed the specific movement information from the initial instructional video. However, in lieu of not receiving the additional demonstrations, the control participants could not refine their technique output throughout practice, and thus failed to display effective motor acquisition of jump shot technique. As a result the control participants demonstrated a disconnect between the motor and cognitive acquisition of a skill. Thus, the opportunity to observe frequent model demonstrations is an essential tool in the effectiveness of acquiring movement technique. Future research should investigate whether there are cognitive and motor acquisition differences between those learners who frequently observe whole model demonstrations throughout practice only, and those who observe segmented skill demonstrations throughout practice only, to determine if there are any robust learning differences.

5.5 Motivation

Research has suggested that when a learner controls an aspect of practice (i.e., augmented information) they have more potential to increase their motivation to learn the task (i.e., Chiviacowsky & Wulf, 2002, 2005; Janelle et al., 1995,1997; Lewthaite & Wulf, 2010; Wulf and Toole, 1999; Wulf et al., 2001, 2005). This is because those who have control of an aspect of practice tend to explore different strategies that are more comfortable, which in turn increase performance confidence, and subsequent motivation (Janelle et al., 1997). In the present research, it was predicted that participants in the self-control condition would report higher motivation-to-learn scores compared to the yoked and control conditions. The results showed no statistically significant motivation score differences between the conditions during each of the time points (before practice, after practice, before retention). Thus, this prediction was not supported

Although there were no statistically significant group differences throughout any of the three motivation checks, the motivation score means at the beginning of practice were higher for the yoked participants (84%), compared to the control (74%) and self-control participants (68%). The same pattern occurred at the end of practice with the conditions displaying motivation scores of 86%, 78%, and 76% respectively (yoked, control, self-control). However, in retention the self-control participants reported the highest motivation scores (82%) compared to the yoked (79%), and control (74%) conditions (for all aforementioned scores see Figure 7). Therefore it is assumed that the majority of the participants in all the conditions were highly motivated to learn the jump shot. As suggested in previous research, one may motivate themselves based on the prediction of self-satisfaction when reaching perceived goals (Bandura, 1975, 1986; Nicklin & Williams, 2011). Thus, if the participants' perceived goal was to acquire the basketball jump shot technique, than it is likely that they would report motivation scores based on the anticipated feeling of meeting that goal. It is also possible that since the task was novel, participants may have reported higher motivation scores due to the ability to learn a new skill, specifically a complex sport skill. Previous motor learning research has not directly measured motivation as a function of self-controlling model demonstrations, however reports of high motivation-to-learn, regardless of practice condition (feedback) has been exhibited (Lewthwaite & Wulf, 2010). Future research should modify the motivation questionnaire used the present research study (*adapted from:* Lewthwaite & Wulf, 2010) to be more sensitive to each practice condition. Perhaps, including specific motivation inquiries (i.e., self-control participants: Given that you have control of the models, how motivated are you to learn the task?) to explicitly measure motivation as a function practice condition (i.e., self-control of skill segments).

5.6 Implications

The present research has expanded our knowledge and may offer valuable applications to coaching philosophy. Research has thoroughly demonstrated skill acquisition as result of whole model observation (*see,* Wrisberg & Pein, 2002; Wulf et al., 2005). Essentially, by comparing the current technique results with the technique results of Wulf and colleagues (2005), segmented skill demonstrations may in fact enhance technique acquisition efficiency. Furthermore, by comparing the aforementioned results, segmented skill demonstrations may decrease the time needed to generally comprehend the technique components of the skill, as the participants in the current research acquired a greater percentage of technique components after five blocks of practice, compared to those in Wulf and colleagues (2005) research. When investigating the results for model choice, a general selection pattern can be noted (see, Figure 1). It seems that the majority of the self-control participants selected a whole-segment-whole model observation strategy. That is they selected the whole model demonstration most frequently during the initial and final blocks of practice, and the segmented model most frequently throughout the middle blocks of practice. This suggests that adopting this whole-segmented-whole learning strategy proved to be an efficient and effective mode in relating the relevant task information needed to gain a significant motor and cognitive comprehension of the to-be-learnt skill. Thus, perhaps for coaches who are instructing novices or are instructing a novel skill, this method of providing the whole model followed by observation of segmented model demonstration and then whole model demonstration once again is an effective method in maximizing cognitive and motor acquisition and retention. Furthermore, emphasis placed on acquiring proper jump shot technique could translate into future automaticity. Logically, as participants continue practicing and refining their technical output they begin to produce the skill with less cognitive effort and more motor consistency. Thus, providing the segmented model demonstrations throughout practice expedites this process as individuals segregate components of the skill according to their difficulty level, and prompt greater cognitive effort in acquiring the components most related to success (i.e., release angle). If this skill automaticity has been thoroughly demonstrated by the learner, they will be able to transfer it to a real-life setting such as a competitive game (basketball game), and provided that they have a thorough cognitive understanding of the skill's technique components any alterations due to the environmental setting (i.e., defenders blocking your shot) should be easily facilitated and corrected via trial and error learning. Therefore, providing the segmented model demonstrations throughout practice affords the learner greater opportunity gain a cognitive understanding of the technique components, and how to accurately modify them in order to increase the likelihood of skill success.

5.7 Limitations

There are a few limitations in the present experiment that must be addressed. First, the absence of an experimental condition (similar to Wulf et al., 2005) that is only permitted to observe the whole-model demonstration throughout practice. Including a whole model condition would allow the experimenters to investigate the acquisition differences present as a function of observing only segmented model demonstrations and only whole model demonstrations throughout practice. A second limitation of the present study is that all participants were able to view the target throughout practice and retention. Thus, even though the goal of the task was to concentrate on shot form while shooting, it is possible that the target (basketball net) may have provoked participants to concentrate on accuracy while compromising technique. Future research should manipulate the task so that participants cannot see the target while performing the skill. This could be accomplished by placing a curtain in front of the participant while shooting in order to obstruct the view of the basketball net. Occlusion goggles could also be worn throughout practice in order to force participants to use kinematic information (i.e., movement sequences) to acquire the basketball jump shot. A third limitation to the present experiment is that the participants were forced to produce their jump shot within a 15 second time frame. Restricting the participants to a time constraint could have provoked unnecessary anxiety, and subsequent skill error. Perhaps future research should allow an unlimited timeframe for each of the participant's jump shot in order to eliminate uncomfortable environments or learner anxiety. Lastly, the fourth limitation to the present experiment was that the basketball jump shot was always required to be shot from the same location (center of free throw line) throughout practice and retention. Thus, participants could have been demonstrating skill acquisition as a function of practicing in a consistent environment. Perhaps future research could utilize a transfer test in which all participants are required to shoot from different distances and locations within the three-point key.

5.8 Summary

Conclusions extracted from the current thesis suggest that perhaps the most efficient method to cognitively and physically acquiring a sport skill (i.e., basketball jump shot) is to provide a detailed observational instruction set, followed by a combination of continuous physical practice and choice to observe skill segment demonstrations, in addition to whole and no model demonstration (i.e., self-control condition). Also, that self-control practice warrants unique learning patterns (i.e., choice of augmented information), which are individualized and cannot be regulated into uniform instruction guidelines for others to comply to.

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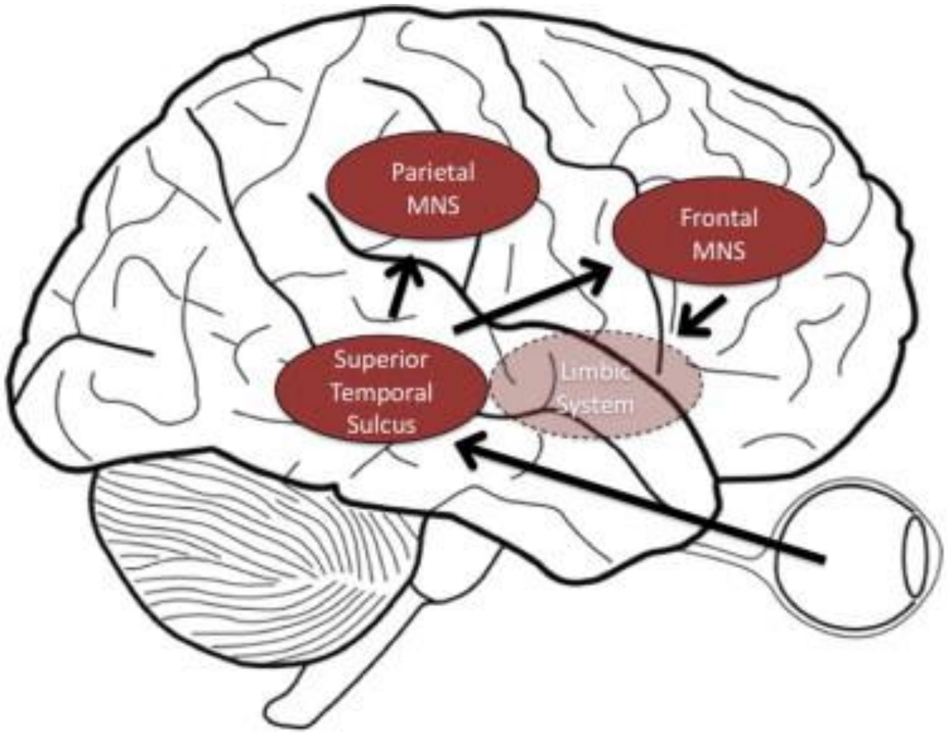
Appendix A

Activated Brain Areas

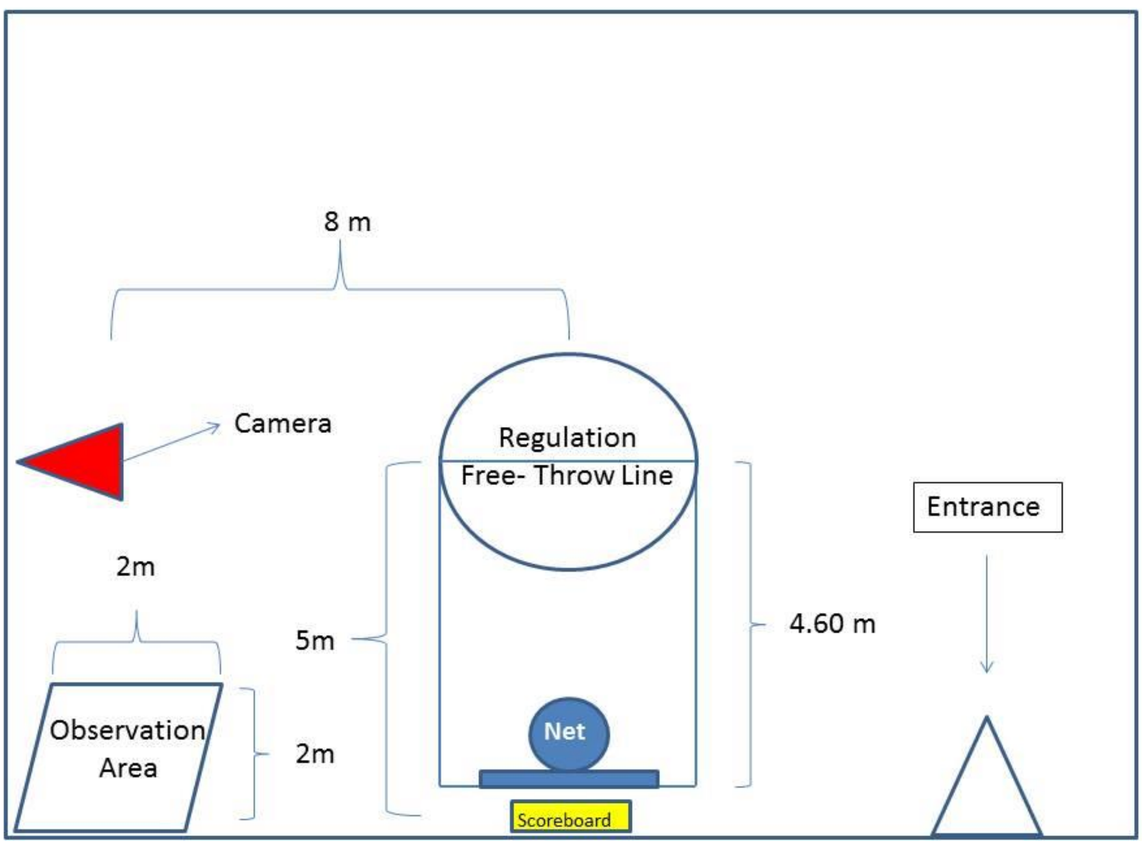


Activated Brain Ares (Mirror Neuron System)
- Adopted from Buccino et al. 2004

Appendix B
Apparatus

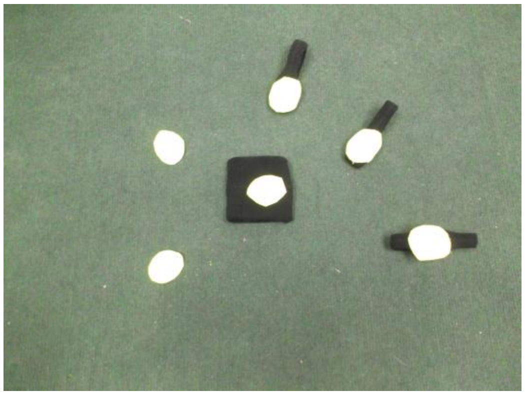
Sagittal View (Camera viewpoint)

Apparatus Layout



Appendix C

Kinematic marker on Under Armour sweatband



Location of Marker on Participants Body

Appendix D

Instructional Video: Biomechanical Components of the Basketball Jump Shot

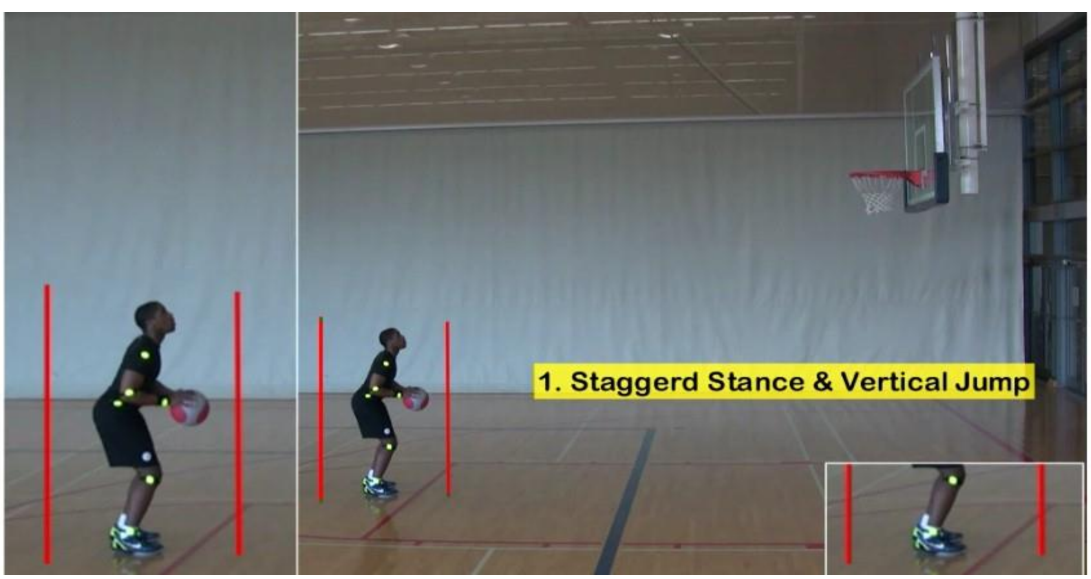
Original video:

Staggered Stance & Vertical Jump:

1. Staggered Stance & Vertical Jump

(co-ordination component 1)

- A base of support slightly less than shoulder width, slightly staggered with the shooting side foot forward
- Minimize horizontal motion by jumping as close to the vertical as possible



Aligned Shooting Plane:

2. Aligned Shooting Plane
(co-ordination component 2)

- Keep shooting side of body aligned with the basket and as close to the vertical as possible

- Shooting forearm lined up with the basket

Co-ordination of Upper and Lower Extremities:

3. Co-ordination of Upper & Lower Extremities
(co-ordination component 3)

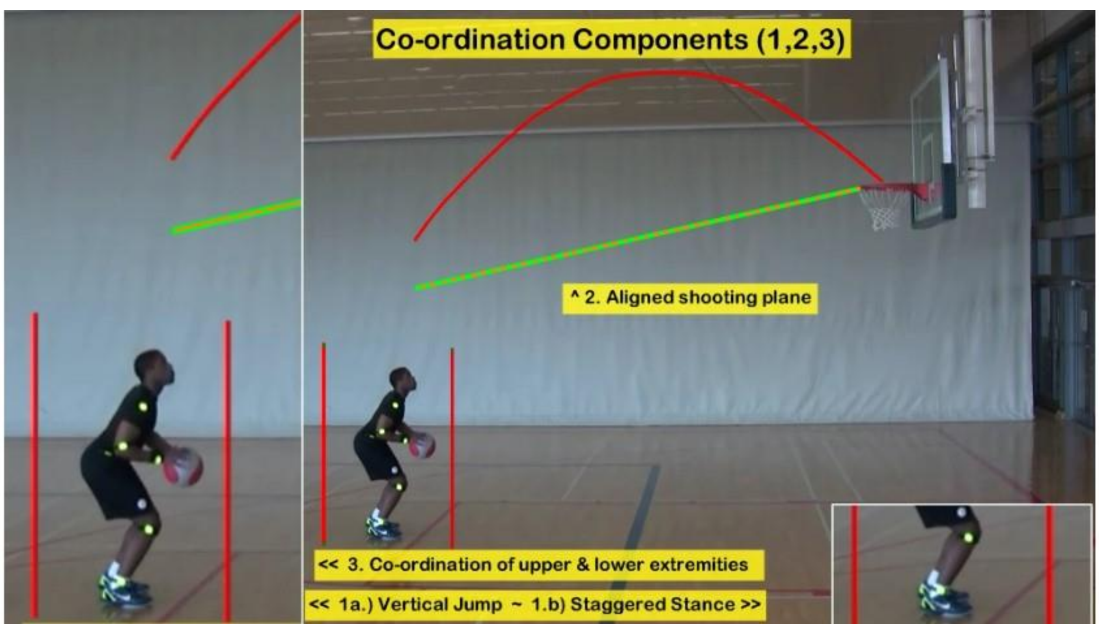
- Integration of a combined upper and lower body extremity action, without overreliance on either

All coordination components:

Brock University

MOTOR SKILLS Acquisition Lab

The model will now demonstrate all three of the co-ordination components (*staggered stance & vertical jump, aligned shooting plane, co-ordination of upper and lower extremities*) being performed in unison

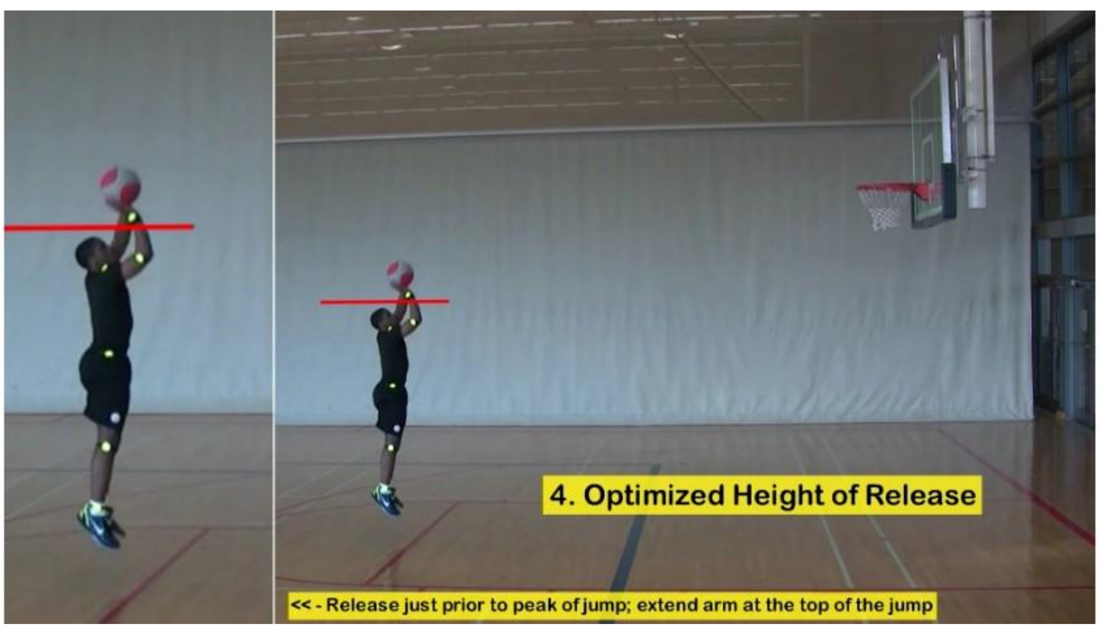


Optimized Height of Release:

4. Optimized Height of Release

(release component 1)

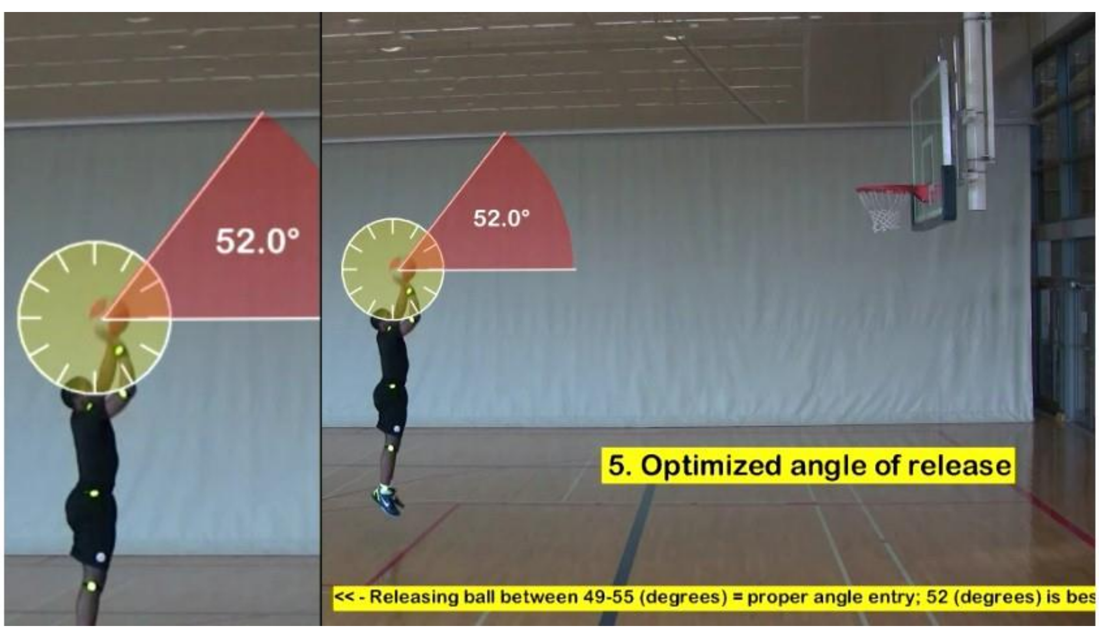
- Balanced jump, flexion of shoulder at release just prior to the peak of the jump
- Extend at the top of the jump



Optimized Angle of Release:

5. Optimized Angle of Release
(release component 2)

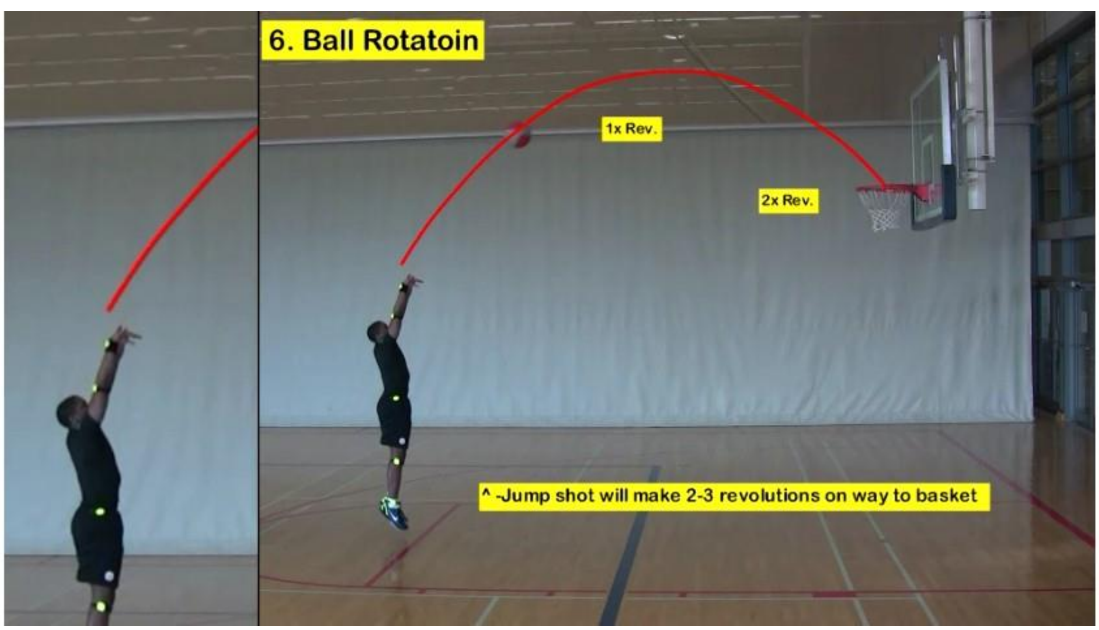
- Shoot the ball 52° above the horizontal
- Shooting the ball between 49°-55° ensures a proper angle of entry and minimizes ball speed



Ball Rotation:

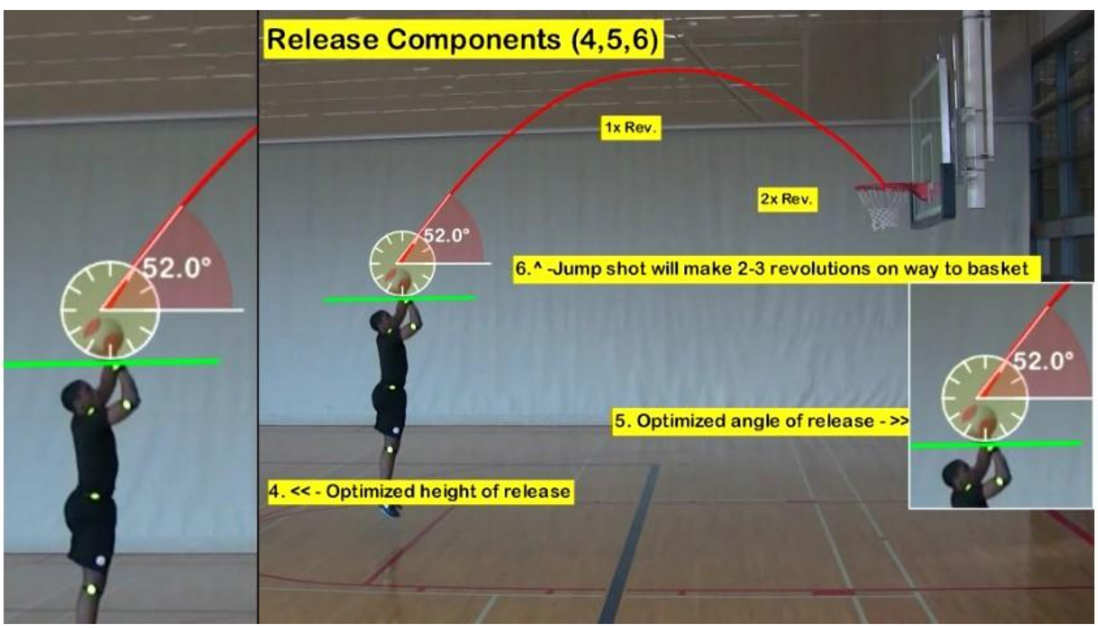
6. Ball Rotation
(release component 3)

- Typical 15 ft. *(foul line)* shot will make 2 to 3 revolutions on the way to the basket
- Utilizing a controlled vigorous wrist flexion and pronation at the release facilitates ball rotation



All release components:

The model will now demonstrate all three of release components (*optimized height of release, optimized angle of release, ball rotation*) being performed in unison



Appendix E:

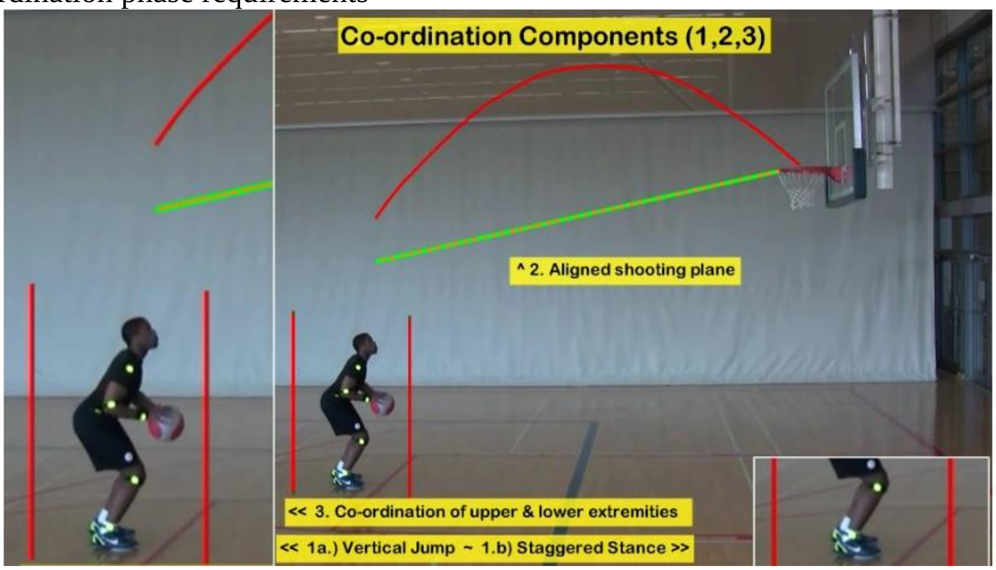
Dartfish Software Video Analysis

Dependent Variables

Component	Score (1 = recognized, 0= not recognized
1. Staggered Stance & Vertical Jump	
2. Aligned Shooting Plane	
3. Co-ordination of Upper & Lower Extremities	
4. Optimized Height of Release	
5. Optimized Angle of Release	
6. Ball Rotation	

[Knudson, 1993]

Co-ordination phase requirements



Release phase requirements:

Participant code number: *Please score accordingly:* **1=** component recognized **0=** component not recognized					
Block #:	**Trial (s)**				
	1	*2*	*3*	*4*	*5*
Biomechanical Components					
1. *Staggered Stance*					
2. *Vertical Jump*					
3. *Aligned Shooting Plane*					
4. *Co-ordination of upper & lower extremities*					
5. *Height of Release*					
6. *Angle of Release*					
7. *Ball Rotation*					
Total Score:					

Appendix F

Accuracy Scoring System (Adapted by Wulf et al., 2005)

Score	**Description of Result**
0	- Unsuccessful, 'air ball'
1	- Unsuccessful, interaction with backboard only
2	- Unsuccessful, interaction with rim and backboard
3	- Unsuccessful, interaction with rim
4	- Successful shot
5	- Successful shot, 'swish'

Accuracy Score sheet

Participant code number: *(see table 1 for scoring guide)*										
	Blocks									
Trial (s)	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1										
2										
3										
4										
5										
10										
Total Score:										

Appendix G
Anthropometric Measurements

Participant Profile	Age	Height (cm)	Right Arm Length (cm)
101	24	169	74
102	24	171	83
103	20	157	57
104	23	154	56
105	22	169	66
106	23	158	57
107	23	183	71
108	24	169	64
109	24	182	79
110	24	173	69
111	28	176	69
114	24	185	80
Mean	23.58333333	170.5	68.75
SD	1.831955405	10.2380751	9.225705196
201	21	183	71
202	20	159	63
203	21	170	68
204	18	177	77
205	24	176	75
206	23	178	72
207	21	163	62
208	21	172	67
209	17	157	69
210	20	173	65
211	22	167	71
212	22	172	68
Mean	20.83333333	170.5833333	69
SD	1.94624736	7.85618845	4.512608599
301	25	178	75
302	22	185	79
303	20	172	69
304	25	181	72
305	23	172	67
306	21	172	68
307	23	192	87
308	20	178	75
309	25	179	77
310	30	166	65
311	23	172	67
314	24	177	72
Mean	23.41666667	177	72.75
SD	2.745519766	6.954396909	6.2830942

Appendix H

Previous Sport Questionnaire **I.D. ________.**

1. Please indicate (circle selection) which sports you have previously played?

2. Also, please indicate the number of years you have played that sport and what skill level you consider yourself to be (i.e. novice, intermediate, or expert) in that specific sport?

Sport	**Years Played**	**Skill Level** *(novice, intermediate or expert only)*
Archery		
Baseball		
Basketball		
Bowling		
Football		
Soccer		
Hockey		
Volleyball		
Golf		
Rugby		
Badminton		
Tennis		
Squash		
Weightlifting		
Lacrosse		
Rowing/Canoe/Kayak		
Skiing/Snowboard		
Softball		
Handball		
Boxing		
Mixed Martial Arts		
Cricket		
Ultimate Frisbee		
Endurance Running		
Swimming Sports		
Pool/Billiards		
Gymnastics		
Dance		
Other:		
Other:		

Appendix I

Self-control Questionnaire

<u>Question</u>	<u>Response</u> 1= Not at all 10= Very Much *(please circle one number)*
1. I am good at resisting temptation	**1—2—3—4—5—6—7—8—9—10**
2. I have a hard time breaking bad habits	**1—2—3—4—5—6—7—8—9—10**
3. I am lazy	**1—2—3—4—5—6—7—8—9—10**
4. I say inappropriate things	**1—2—3—4—5—6—7—8—9—10**
5. I do certain things that are bad for me, if they are fun	**1—2—3—4—5—6—7—8—9—10**
6. I refuse things that are bad for me	**1—2—3—4—5—6—7—8—9—10**
7. I wish I had more self-discipline	**1—2—3—4—5—6—7—8—9—10**
8. People would say that I have iron self-discipline	**1—2—3—4—5—6—7—8—9—10**
9. Pleasure and fun sometimes keep me from getting work done	**1—2—3—4—5—6—7—8—9—10**
10. I have trouble concentrating	**1—2—3—4—5—6—7—8—9—10**
11. I am able to work effectively toward long-term goals	**1—2—3—4—5—6—7—8—9—10**
12. Sometimes I can't stop myself from doing something, even if I know it is wrong	**1—2—3—4—5—6—7—8—9—10**
13. I often act without thinking through all the alternatives	**1—2—3—4—5—6—7—8—9—10**

Appendix J

Motivation Questionnaire (Adapted from Lewthwaite & Wulf 2010**)**

Task Related Responses	Questions	Response (1-10) 1= “not at all”, 10= “very”
Task Related Responses	1. How motivated were you to learn this task?	
Task Related Responses	2. How much did you enjoy practicing this task?	
Task Related Responses	3. How much are you looking forward to your next session?	

(Adapted from Lewthwaite & Wulf, 2010)

Appendix K

RPE Questionnaire (Borg, 1982)

Table 5.2A The original Borg Scale Rating Perception of Effort (RPE)

Rating	Perception of effort
6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very, very hard
20	

Appendix L

Recall Test

Please list each of the seven biomechanical components to the basketball jump shot?

Component
1.
2.
3.
4.
5.
6.
7.

(adapted from Knudson, 1993)

Appendix M

Experimental Flow-Chart